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RECOMMENDED GEOTECHNICAL FIELD INVESTIGATIONS. VOLUME III.(U)
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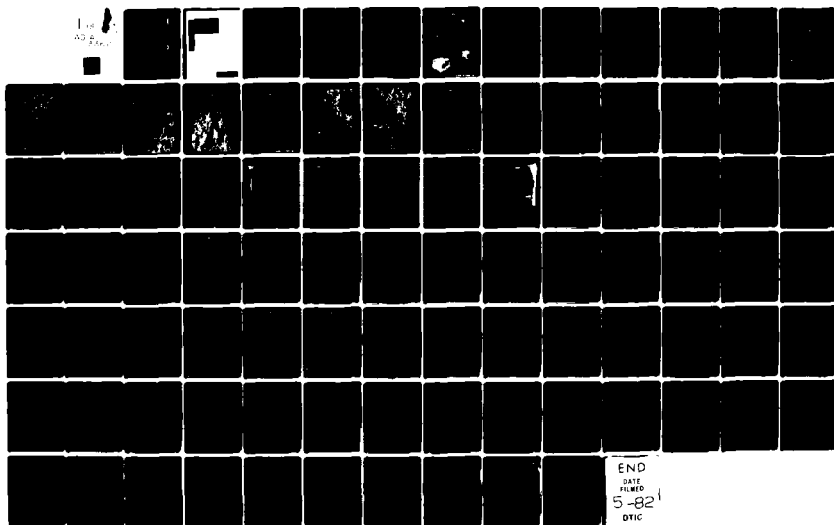
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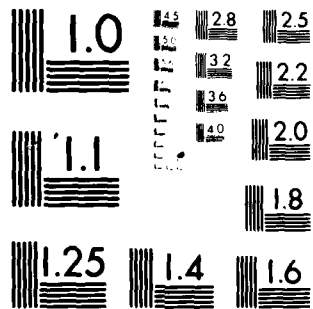
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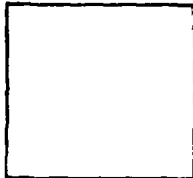
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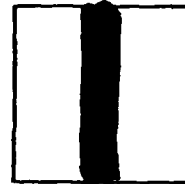
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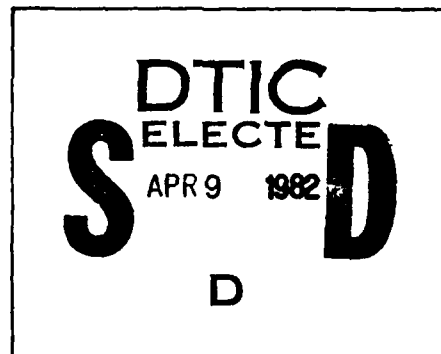
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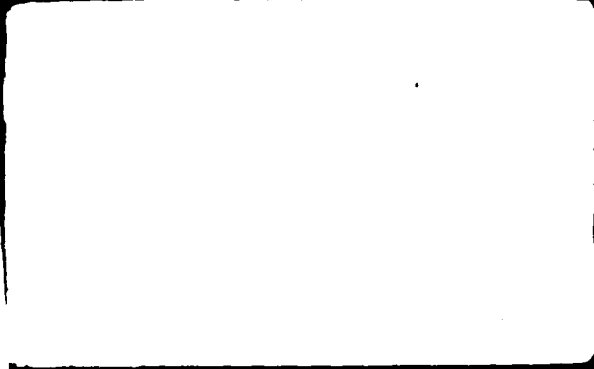
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**RECOMMENDED GEOTECHNICAL
VOL. II
FIELD INVESTIGATIONS**

Conducted for:

**DEPARTMENT OF THE AIR FORCE
SPACE AND MISSILE SYSTEMS ORGANIZATION (SAMSO)**

Contract No. F04701-74-D-0013

By:

FUGRO NATIONAL, INC.

Project No. N74-066-EG

31 May 1976

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Draft geotechnic report on cultural and quantity distance exclusions, topographic grade exclusions for potential siting of MX shelters in at The Nellis Group, Nevada, The Gila Bend Group, Arizona and The White Sands Missile Range Extension, New Mexico.		

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1

1.0 INTRODUCTION

1.1 FORWARD

This report was prepared for the Department of the Air Force, Space and Missile Systems Organization (SAMSO), in compliance with conditions of the statement of work as part of Contract No. F04701-74-D-0013 and deals with siting of the MX Land Mobile Advanced ICBM system. This contract was authorized under Program Element 63305F as described in the 26 February 1973 Missile X Program Plan.

The report was prepared for SAMSO by Kenneth L. Wilson, Senior Geologist; and James R. Miller, Project Geologist, with final graphics preparation by Edd V. Joy and James A. Nenneman. TRW Systems personnel monitored the study for SAMSO.

The overall Geotechnical Evaluation Investigation, upon which this report is based, dealt with two Bureau of Land Management (BLM) areas and one Department of Defense (DoD) co-use area (Figure 1): the Nellis Group (NG), Nevada; the Gila Bend Group (GBG), Arizona; and the White Sands Missile Range Extension (WSE) hereinafter called BLM land, New Mexico. As shown in Figure 1 the three DoD siting areas lie within or immediately adjacent to the BLM areas. The BLM lands encompass a total of approximately 13,885 square nautical miles (nm^2).

Results of the total MX Siting Investigation Geotechnical Evaluation are presented in a written format and as large



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(37" x 42") map and overlay graphics. Written materials are presented in four volumes which specifically consist of:

Volume I	Siting Evaluation Report.
Volume IIA, IIB, and IIC	Geotechnical Reports IIA White Sands Missile Range Extension IIB Gila Bend Group IIC Nellis Group
Volume III	Recommended Geotechnical Field Investigations

Important to siting considerations are contiguity of and accessibility between land areas suitable for siting. The Valley Analysis Concept has been introduced to enhance data depiction and usability. A valley (designated by capitalized "V") is a sub-area of the BLM/Co-use siting area and may be composed of portions of one or more four-quad sheets for which geotechnical data may be compiled. The Valley definition for the BLM geotechnical reports differs somewhat from the Valley definition for the DoD geotechnical reports (Table 1). The major difference is that the mountains, which comprise most of the greater than ten percent topographic grade areas in the DoD Valleys, are not part of the BLM Valleys.

Typically, a BLM Valley includes an alluvial lowland area and excludes the flanks of its bordering mountain ranges. A geographic valley, as designated and named on existing maps, may encompass a portion of, or include the entire alluvial lowland area of a Valley. Most often Valley names correspond with the appropriate geographic valley name.

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TABLE 1

VALLEY TERMINOLOGY - BLM - DOD STUDY AREA

Department of Defense Lands

A Valley (designated by Capitalized "V") is a sub-area of DoD siting area.

It is bound by one or both of the following:

1. A hydrologic drainage divide (most often the crest of an intervening mountain range); and
2. DoD boundary or any other artificially established boundaries such as public highways, township and range lines or national monument borders.

Bureau of Land Management Lands

A Valley (designated by capitalized "V") is a sub-area of a BLM siting area. It is bound by one or more of the following:

1. Areas of greater than ten percent topographic grade;
2. Large exclusion areas such as National Forests, Indian reservations or quantity-distance areas;
3. DoD boundary or any other artificially established boundaries such as public highways, townships and range lines, latitude lines; and
4. A hydrologic drainage divide (most often at a low relief intervalley connection).

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There are thirty-six Valleys within the BLM area (Figures 2, 3, and 4). The area within a designated Valley which is available for siting based only on cultural and quantity-distance exclusions and general topographic conditions (less than ten percent grade) is referred to as the siting valley.

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1.2 PURPOSE AND SCOPE

The purpose of this report is to:

- 1) Define the basic geotechnical parameters necessary to evaluate MX siting suitability from both construction and nuclear weapons effects standpoints.
- 2) Recommend a phased program of field and laboratory investigation that will provide the geotechnical information required to permit proper evaluation of siting suitability.

Utilizing the results of our literature-based geotechnical investigation presented in Volumes IIA and IIB, this report presents the recommended field program including:

- 1) The basis for a three-phased investigation.
- 2) Descriptions of the concept and content of each phase.
- 3) Status of existing data summarized from a qualitative analysis of data presented in the Data Summary Sheets of Volumes IIA, IIB, and IIC.
- 4) Recommended field investigative techniques, the data to be derived through the use of each, and the level of effort to which each technique will be employed in each siting area.
- 5) Identification of geotechnical factors unique to either of the two siting concepts (shelters and trenches).

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1.3 PROGRAM REQUIREMENTS

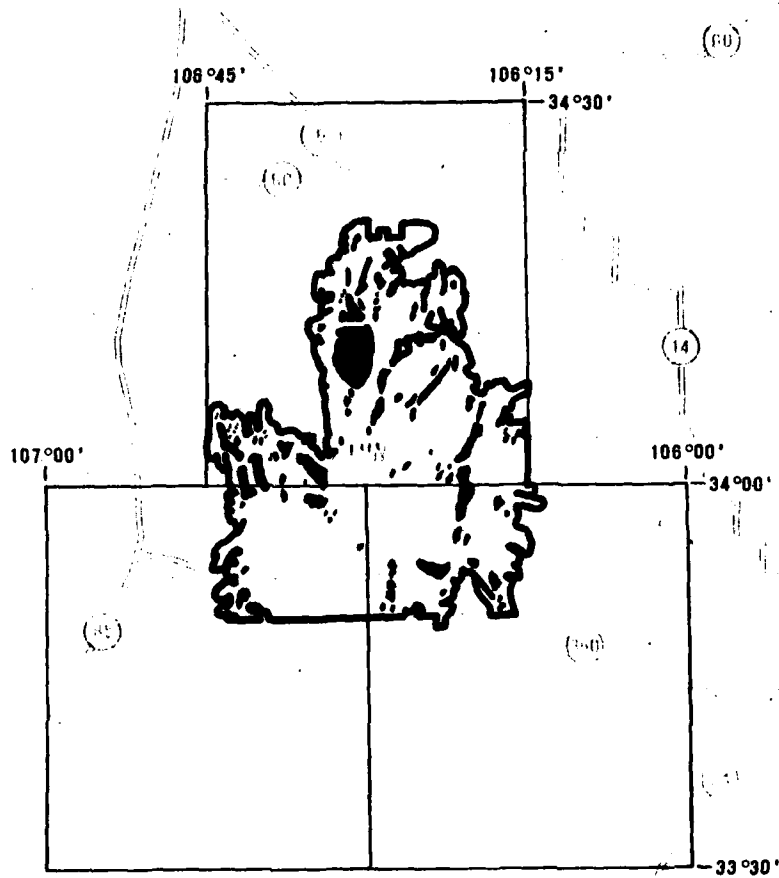
1.3.1 GENERAL

Available areas considered for field investigation are those portions of the BLM valleys remaining after applying cultural and quantity-distance exclusions, and ten percent grade exclusions (white areas of Figures 2, 3 and 4). The proposed investigation considers two concepts, buried trench (Figure 5) and shelter (Figure 6), and is designed to provide data applicable to both, as well as data with unique application to each concept.

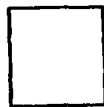
The geotechnical investigations are designed to yield data applicable to design for construction considerations and analysis of vulnerability and hardness of the MX system. Most of the important construction related considerations for the system will be investigated within approximately 100 feet below the ground surface. Vulnerability and hardness related to nuclear weapons effects are more dependent upon subsurface conditions to a depth of about 2000 feet. It is necessary to know conditions below a depth of 2000 feet, but with decreasing accuracy.

The geotechnical data are classified into three categories identified as being of principal importance to the siting effort. These are: 1) Depth to Rock, 2) Depth to Water, and 3) Other Parameters which include soils engineering, hydrologic and geologic parameters of surface and near-surface materials, topography, surface hydrology and groundwater considerations.

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EXPLANATION



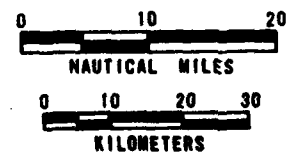
Area of Thirty-Minute Quadrangle Map.



Boundary of BLM valley.



Area of greater than 10% grade within BLM valley.



TOPOGRAPHIC GRADE EXCLUSION AREAS

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SANSO





FIGURE
2

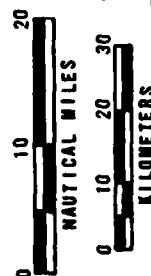
FURRO NATIONAL INC.

DATE: 31 MAY 78

DATE: 31 MAY 76

EXPLANATION

-  Area of Thirty-Minute Quadrangle Map.
-  Boundary of BLM valley.
-  Area of greater than 10% grade.
-  Area of greater than 10% grade within BLM valley

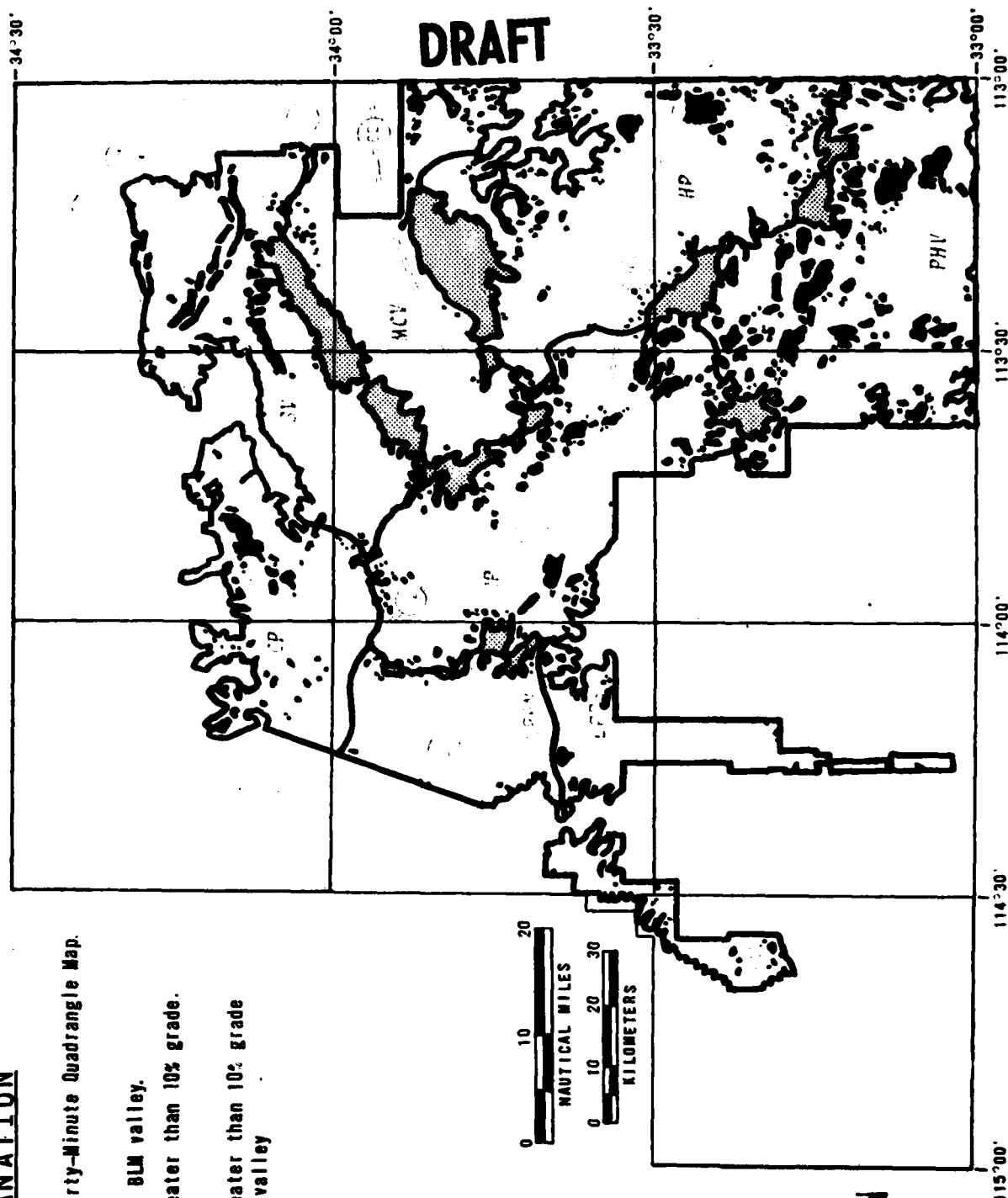


TOPOGRAPHIC GRADE EXCLUSION AREAS

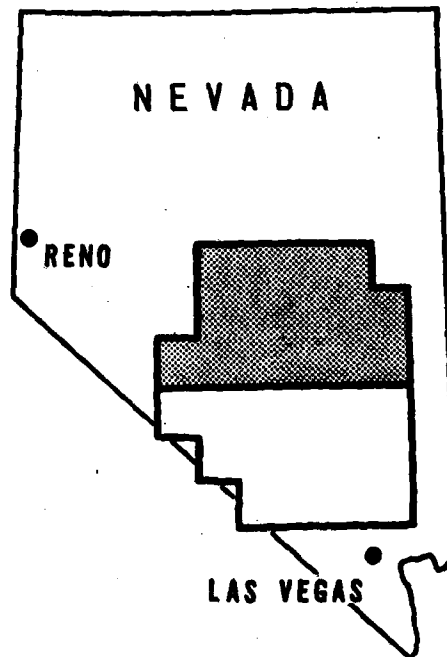
MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMS0

FIGURE
3

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TOPOGRAPHIC GRADE EXCLUSION AREAS

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SANSO

FIGURE
4A

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EXPLANATION



Area of Thirty Minute Quadrangle Map



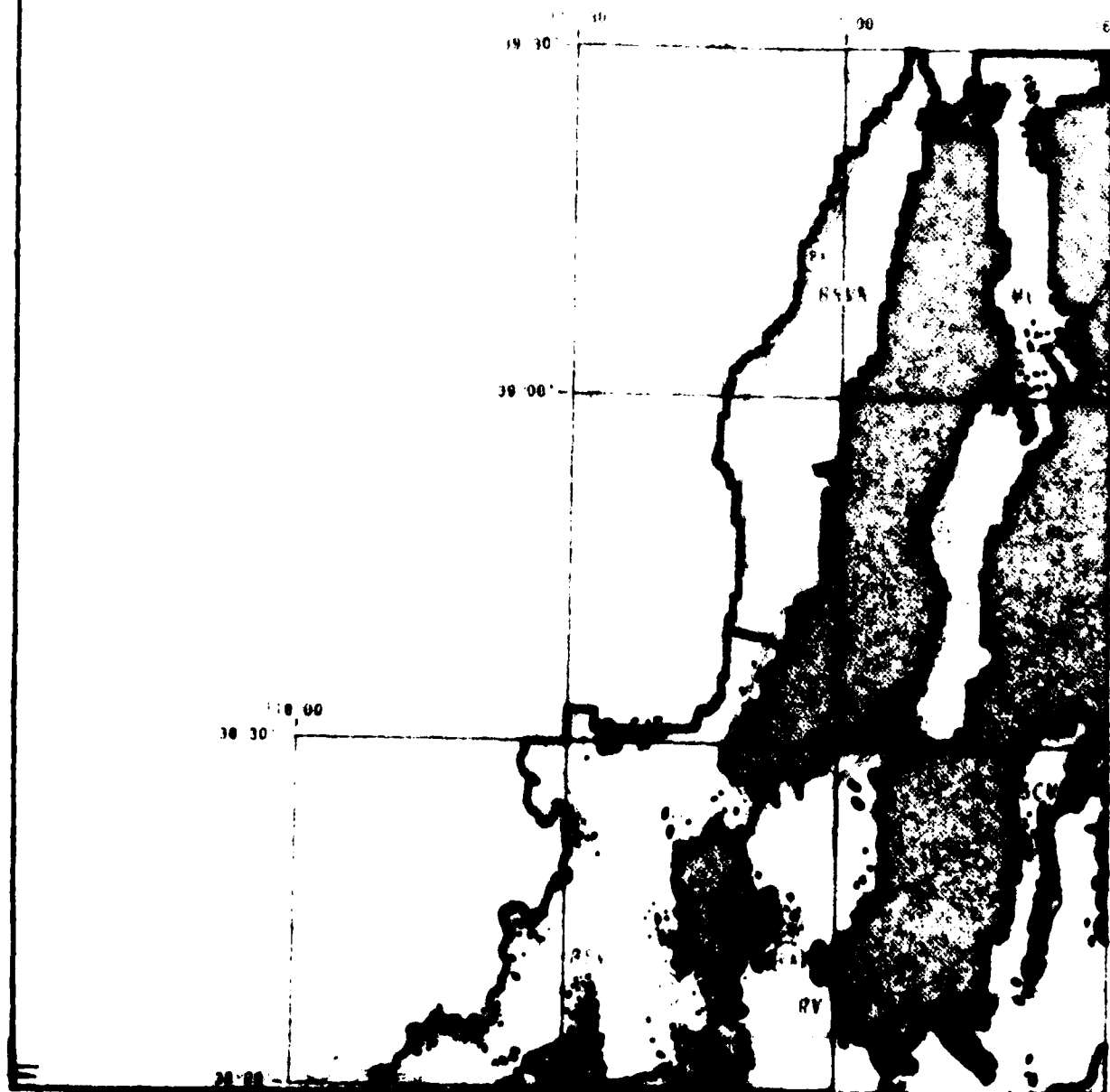
Boundary of BLM valley



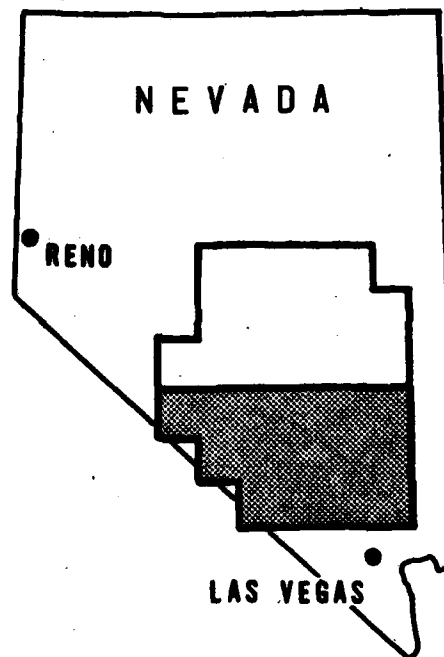
Area of greater than 0% grade
and/or cultural exclusion



Area of greater than 10% grade
within BLM valley



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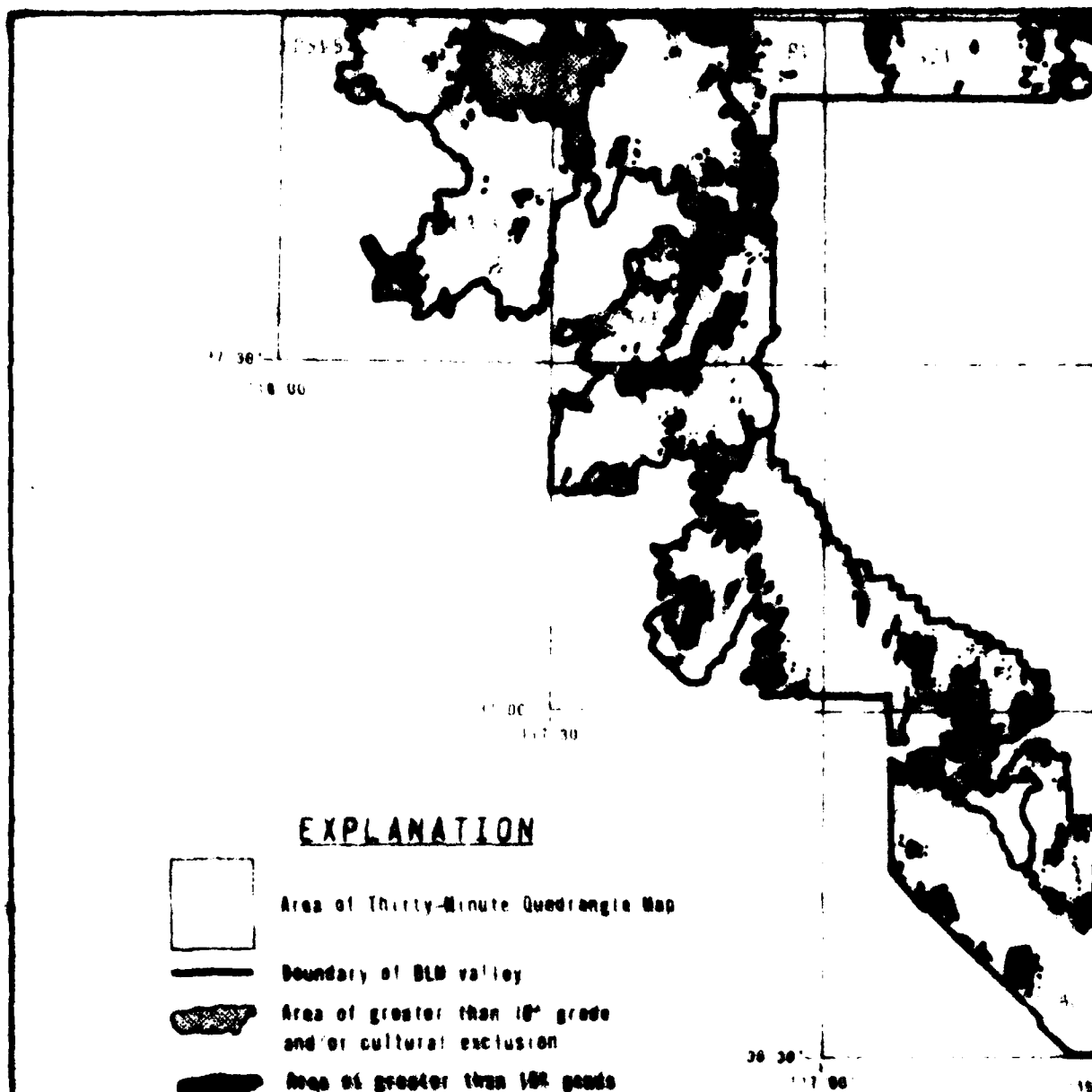
TOPOGRAPHIC GRADE EXCLUSION AREAS

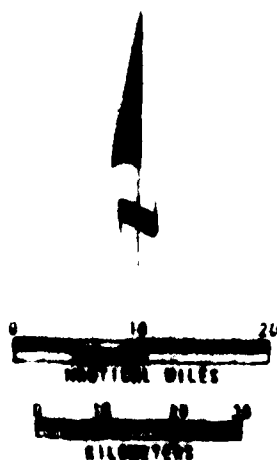
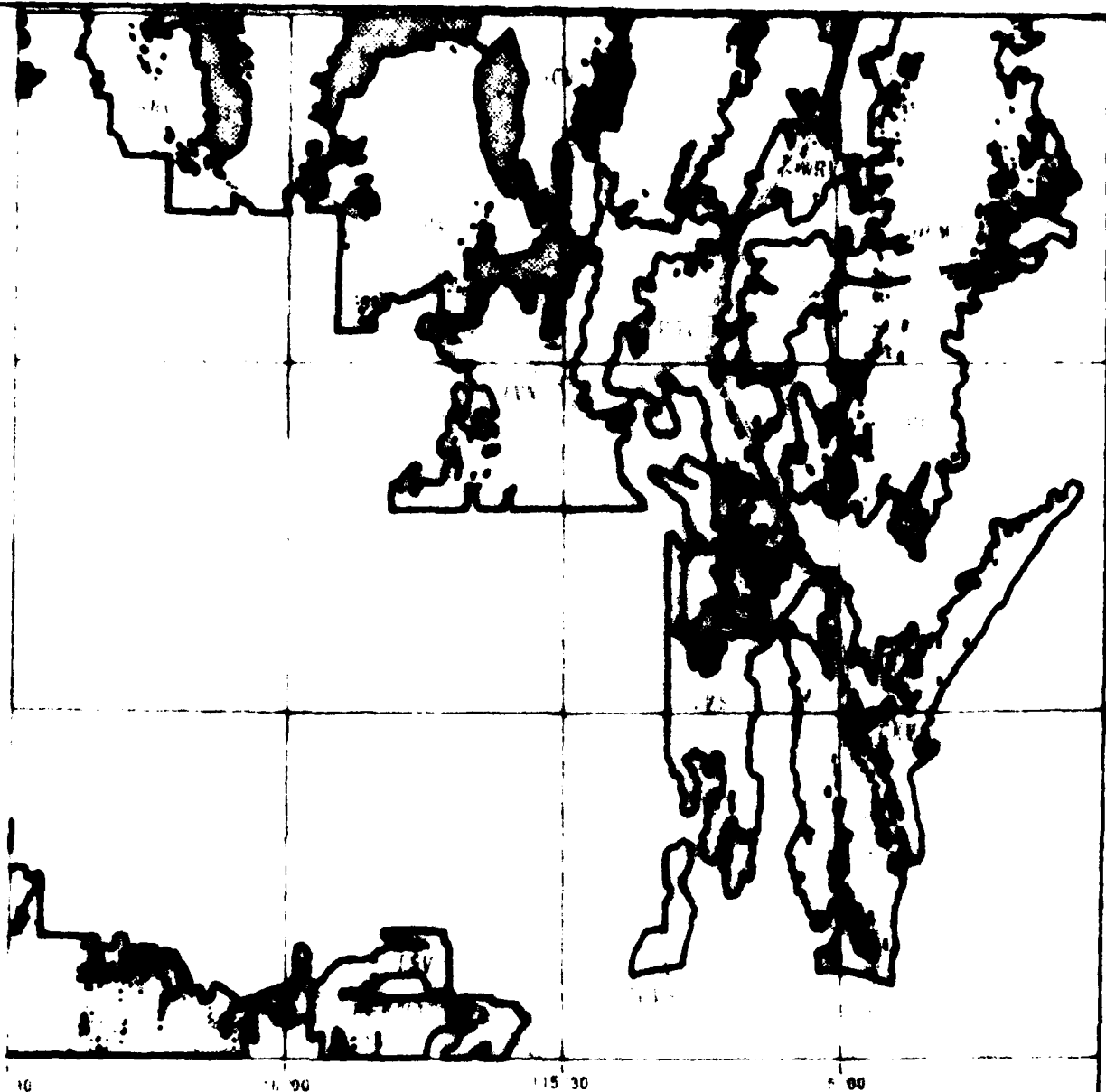
MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SANSO

FIGURE
48

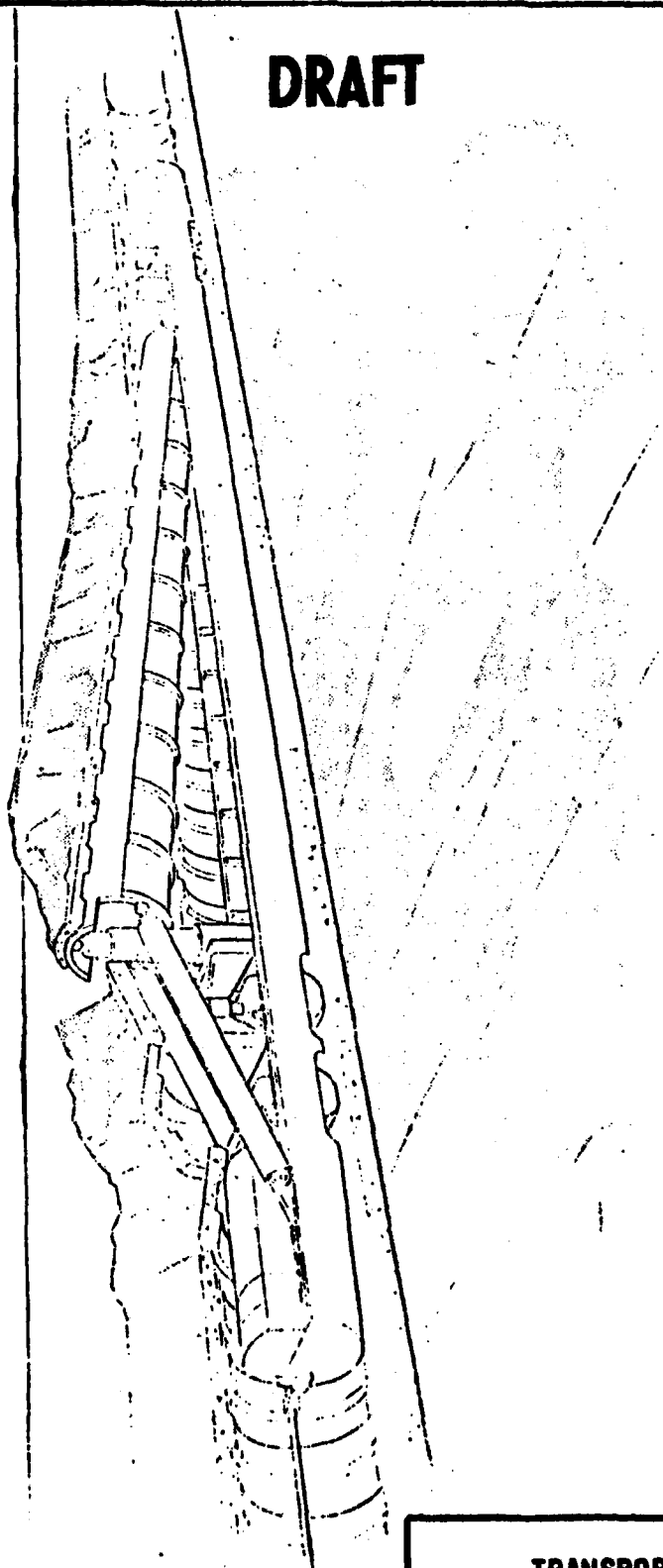
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TRANSPORTER LAUNCHER

**MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SANJO**

**FIGURE
5**

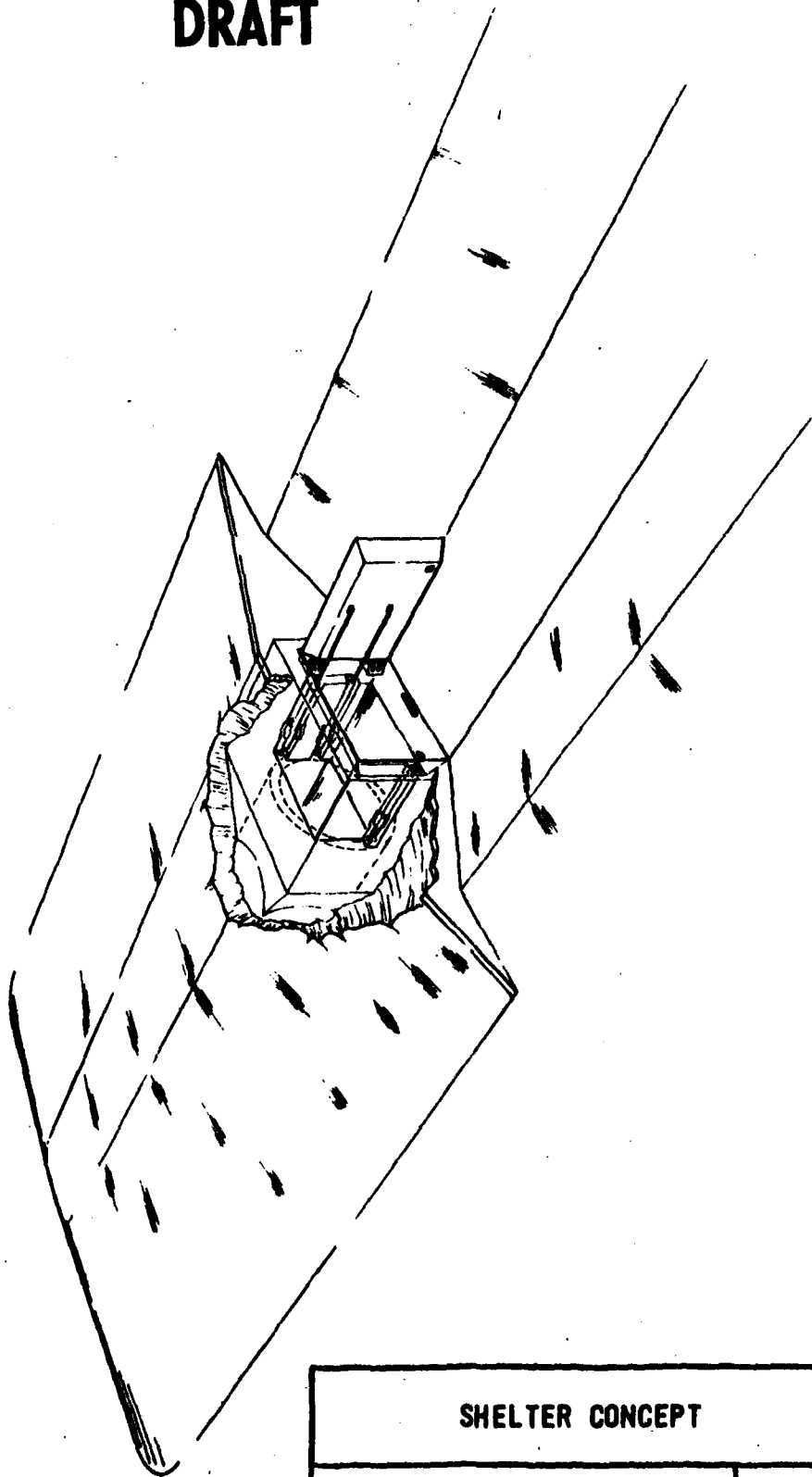
Source: TRW Systems, 1975/

FUERO NATIONAL INC.

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DATE: 31 MAY 1978

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SHELTER CONCEPT

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SANSO

FIGURE
6

FUBRO NATIONAL INC.

Source: TRW Systems, 1976b

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Accuracies required for depth to rock and depth to water data over various depth intervals are assumed to be:

0 to 25 feet	<u>+5%</u>
25 to 250 feet	5-10%
251 to 2000 feet	10-15%
>2000 feet	15-20%

Expected measurement resolution of the selected field techniques is included in Section 4.3.

1.3.2 CONSTRUCTION

Most construction related parameters important to design of the system are accessible to study within approximately 100 feet below the ground surface. The following list of constraints prohibiting construction are known or assumed to apply to either the buried trench (T) or the shelter (S) concepts, or both:

- 1) Areas with depths to water or rock less than 25 feet. (T)
- 2) Areas of unsuitable surface volcanic flow rock. (S,T)
- 3) Areas within 1000 feet of a capable fault. (S,T)
- 4) Areas within primary or major secondary drainages with a high flooding potential. (S)
- 5) Areas of standing water (S,T).
- 6) Areas with known poor soil conditions. (S,T)
- 7) Areas with greater than ten percent grade. (S,T)

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Data requirements known or assumed to apply are as follows:

- 1) Excavatability of materials to depths on the order of 25 feet below ground surface. (S,T)
- 2) Stability of excavations with 25-foot high near-vertical slopes. (T)
- 3) Foundation characteristics to depths of 50 feet below ground surface. (S,T)
- 4) Terrain characteristics (e.g., drainage density, depth of incision, channel morphology). (S,T)
- 5) Surface material strengths and stability under wet and dry conditions. (S,T)
- 6) Availability of water for construction purposes and dust control. (S,T)
- 7) Sources of construction materials (e.g., gravel, sand, limestone, rock). (S,T)
- 8) Potential for flooding in drainages and overland. (S,T)
- 9) Land ownership and area demography. (S,T)

1.3.3 NUCLEAR WEAPONS EFFECTS

Vulnerability and hardness related to nuclear weapons effects are dependent upon conditions to a depth of approximately 2000 feet. The interval from zero to 250 feet below the ground surface is the most critical interval with less accuracy required to 2000 feet. It is necessary to know conditions below 2000 feet with a still lower degree of accuracy. Data requirements to assess potential nuclear weapons effects vary with depth as follows:

- 1) Depths to rock and water to 5000 feet.
- 2) Material properties of the basin fill in detail (e.g., conventional classification, particle size distribution, index tests, moisture content, density) to 250 feet.
- 3) General basin fill properties as obtained from borehole logging from 250 to 2000 feet.
- 4) Seismic velocities (compressional and shear wave) and porosity to 1000 feet, with identification of major high velocity inter-layers (i.e., 5 feet thick caliche or volcanic flow rock with 15,000 feet/second p-wave velocity in upper 250 feet).
- 5) Seismic velocities at depths greater than 1000 feet up to 15,000 feet/second or to 2000 feet, whichever is encountered first.
- 6) Location and attitude of subsurface faults juxtaposing materials with a high velocity contrast within 2000 feet of the ground surface.

1.3.4 NON-FIELD INVESTIGATION TASKS

Ownership determinations for lands in the BLM study area must be refined to a level sufficient to be meaningful in the ranking process of Valley areas in the remaining 12,000 to 14,000 nm² selected for Phase 1 studies (Section 2.1).

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This will require researching state plat maps to determine specific ownership rights and to precisely depict ownership boundaries. Land values will be determined for areas of private ownership.

Flooding potential in BLM (as well as DoD) areas must be estimated for drainages and landforms in the selected land areas. Watershed areas and precipitation-runoff relationships will be determined in order to provide discharge rates for various channel morphologies.

Permits will be obtained, with coordination by SAMSO, to perform Phase 1 field work in the BLM lands. These permits will allow for access to areas for all destructive and non-destructive field activities. Coordination with the environmental contractor to provide an environmental assessment for field work will be necessary prior to obtaining these permits.

2.0 PHASED GEOTECHNICAL PROGRAM

2.1 GENERAL

Field and laboratory work will follow the literature-based geotechnical evaluation of BLM lands. A similarly based evaluation of DoD lands has been performed. Prior to field work a selection of 12,000 to 14,000 nm² will be made from the approximately 26,000 nm² which were evaluated. This 12,000 to 14,000 nm² will be composed of both DoD and BLM land areas which will be ranked according to preference for beginning field work.

A three-phased plan for geotechnical field work is recommended, with each successive phase becoming more comprehensive in scope and concentrating on smaller areas. Phase I will begin with the 12,000 to 14,000 nm² area and end in selection of a 4000 to 6000 nm² deployment area. Primary field techniques involved will be aerial photography, geophysical mapping of subsurface features, surface mapping, exploratory trenches and borings and laboratory testing.

Phase 2 will begin with the selected 4000 to 6000 nm² area and terminate with identification and location of specific system sites (lines or aim-points). Phase 2 will have an increased emphasis on soils engineering data retrieval with a more intensive subsurface investigation by geophysics and drilling along with laboratory and field testing. Surface geologic mapping will continue with emphasis on construction materials, terrain analysis and geologic unit distribution.

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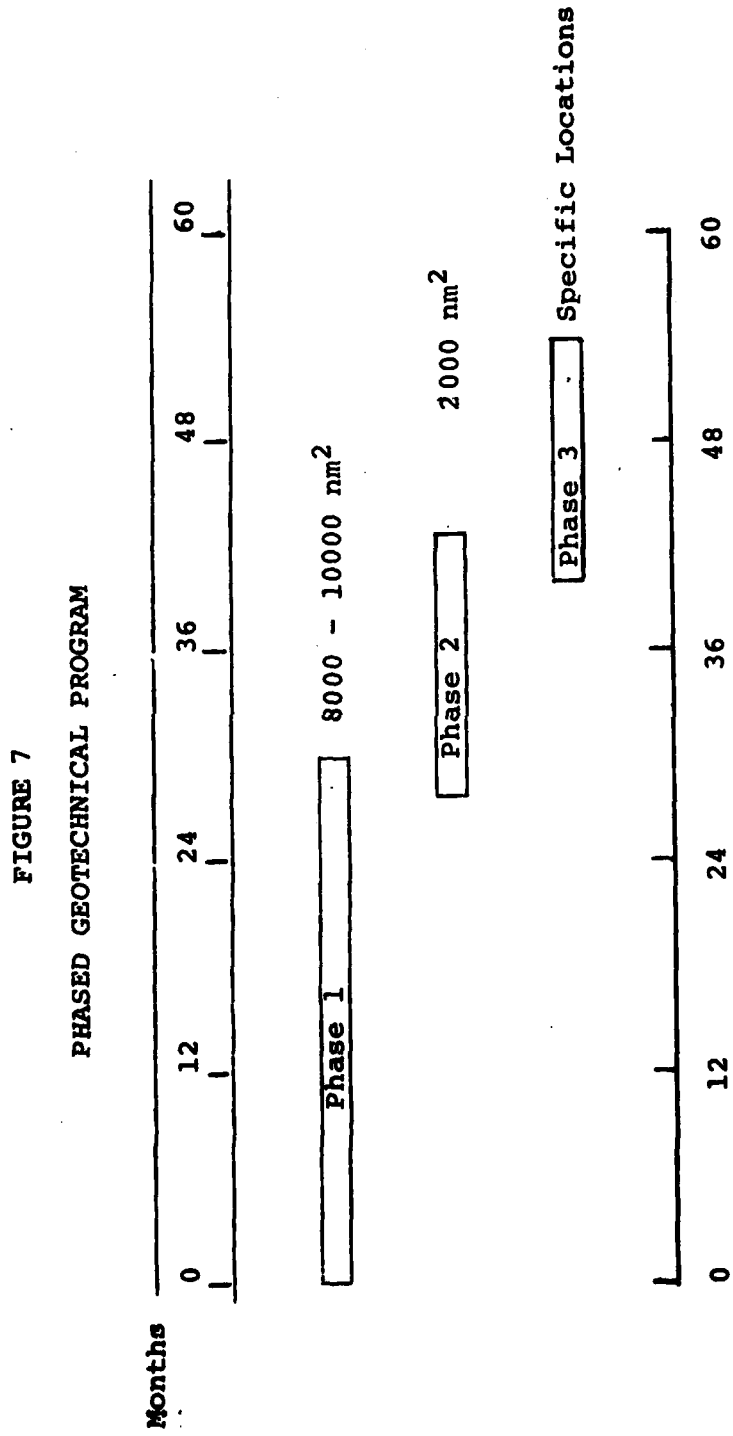
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Phase 3 will be performed to provide geotechnical information for construction of the system at or along each specific location selected. Data will be filled in between the widely spaced data point locations of the previous phases. Construction related data will be obtained from drilling, laboratory and in-situ testing, shallow geophysics and surface mapping.

Although it is not now known what portion of the 12,000 to 14,000 nm² will be within BLM lands, it is assumed for purposes of this report that it will be two-thirds, or approximately 8000 to 10,000 nm². Time estimates for completion of Phase 1 are based on this assumption. Phase studies for BLM lands are assumed to cover 2000 to 3000 nm² or one-half of the final deployment area.

Site specific (hereinafter defined as relating to a specific location selected for a structure) Phase 3 studies are assumed to be for either 9000 shelters or 2250 nm of trench, which equal one-half of the assumed force.

A time line diagram showing the suggested duration and overlap of each phase for the BLM field studies is presented in Figure 7. A starting time of 1 October 1976 is assumed for Phase 1 and durations of each phase are based on manpower requirements presented in later sections.



2.2 INTERRELATIONSHIPS OF PHASES AND FIELD TECHNIQUES

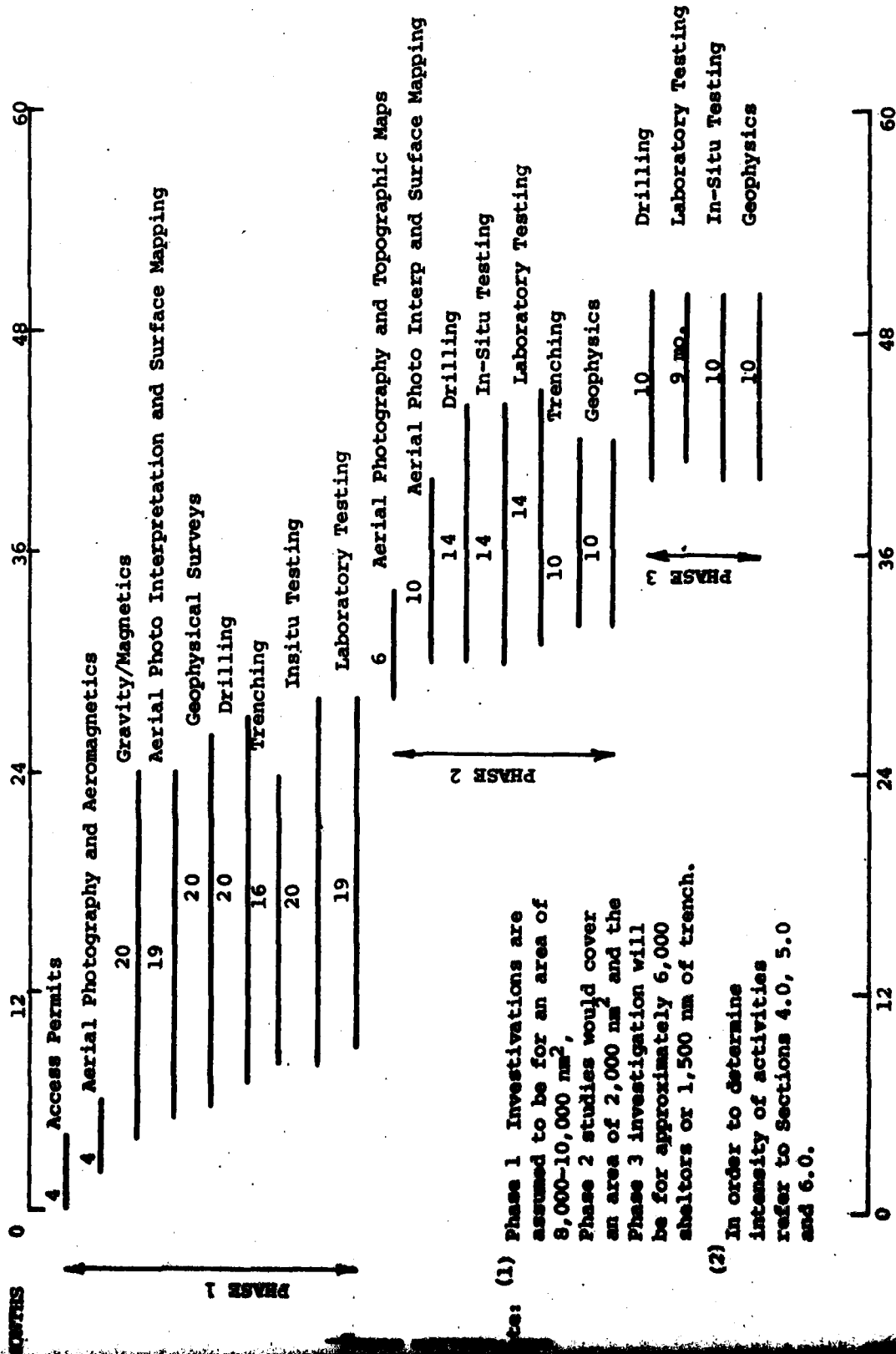
The sequence of field work tasks is shown in Figure 8 to illustrate the interrelationship of the recommended field techniques within each phase. Many techniques have been carried throughout the three phases, but with different relative intensities. Intensity is defined in this context to mean the relative magnitude of the use of any particular investigative technique, e.g. the number of drill holes planned for a unit area. The time to complete a phase is, to a major degree, dependent upon the level of work effort, i.e. a more concentrated level of activity will produce equivalent data more rapidly. Discussions in Sections 4.0, 5.0 and 6.0 cover the planned intensity and level of effort.

Analysis and reporting points should coincide with major systems development milestones and allow for integration of the geotechnical information into the total development scheme. SAMSO review, transfer of information and interim reports will occur throughout the program. Figure 9 illustrates the paths of the various tasks with reference to time or overlap of phases.

A critical element in the total program is the preparation of detailed field plans for all phases. These plans will be specific in outlining all tasks to be completed within each phase. Final preparation of the plans will occur

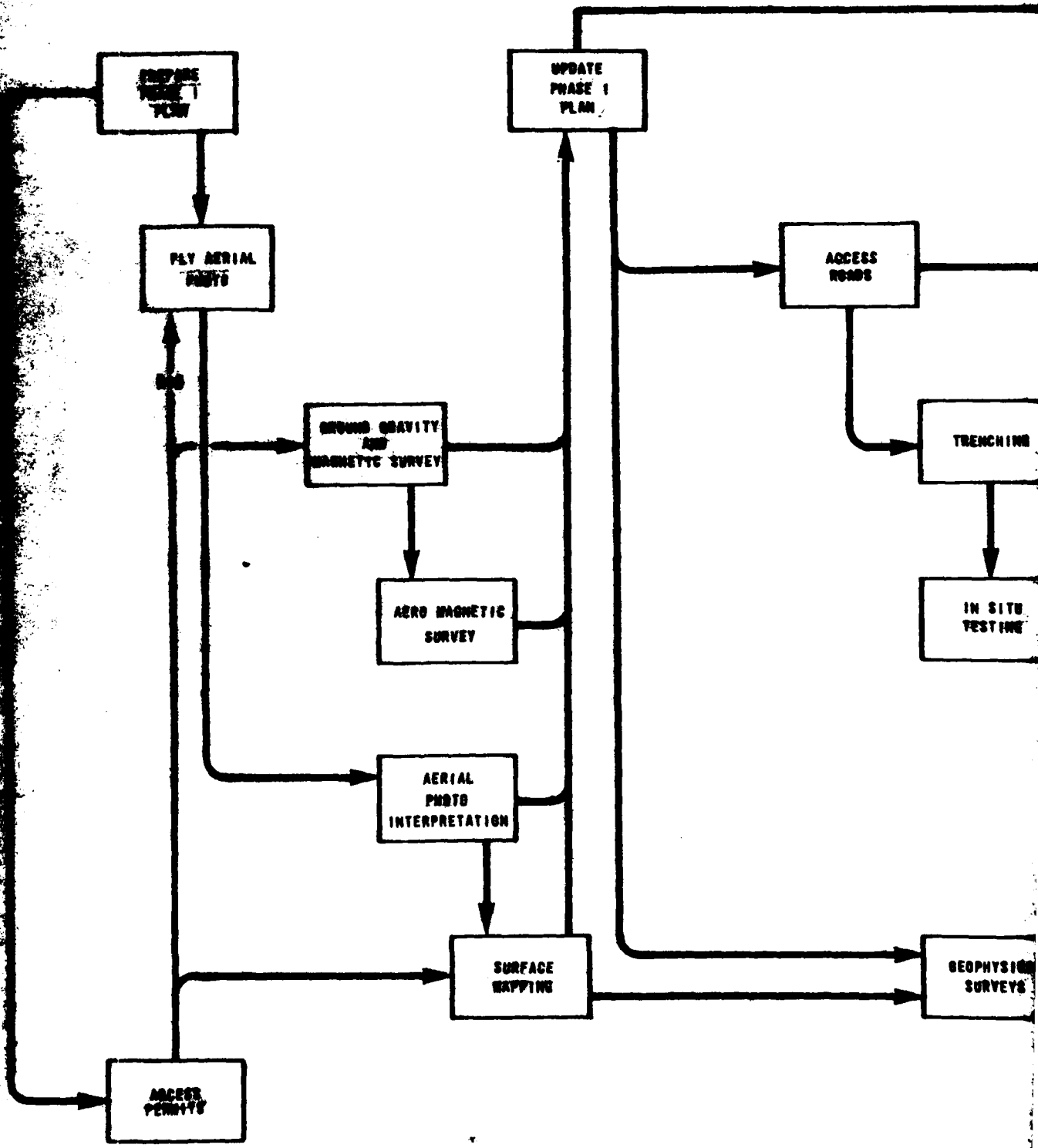
FIGURE 8

INTERRELATIONSHIPS OF PHASES AND FIELD TECHNIQUES



- (1) Phase 1 Investigations are assumed to be for an area of 8,000-10,000 nm², Phase 2 studies would cover an area of 2,000 nm² and the Phase 3 investigation will be for approximately 6,000 sheltors or 1,500 nm of trench.
- (2) In order to determine intensity of activities refer to Sections 4.0, 5.0 and 6.0.

DATE: 31 MAY 1976



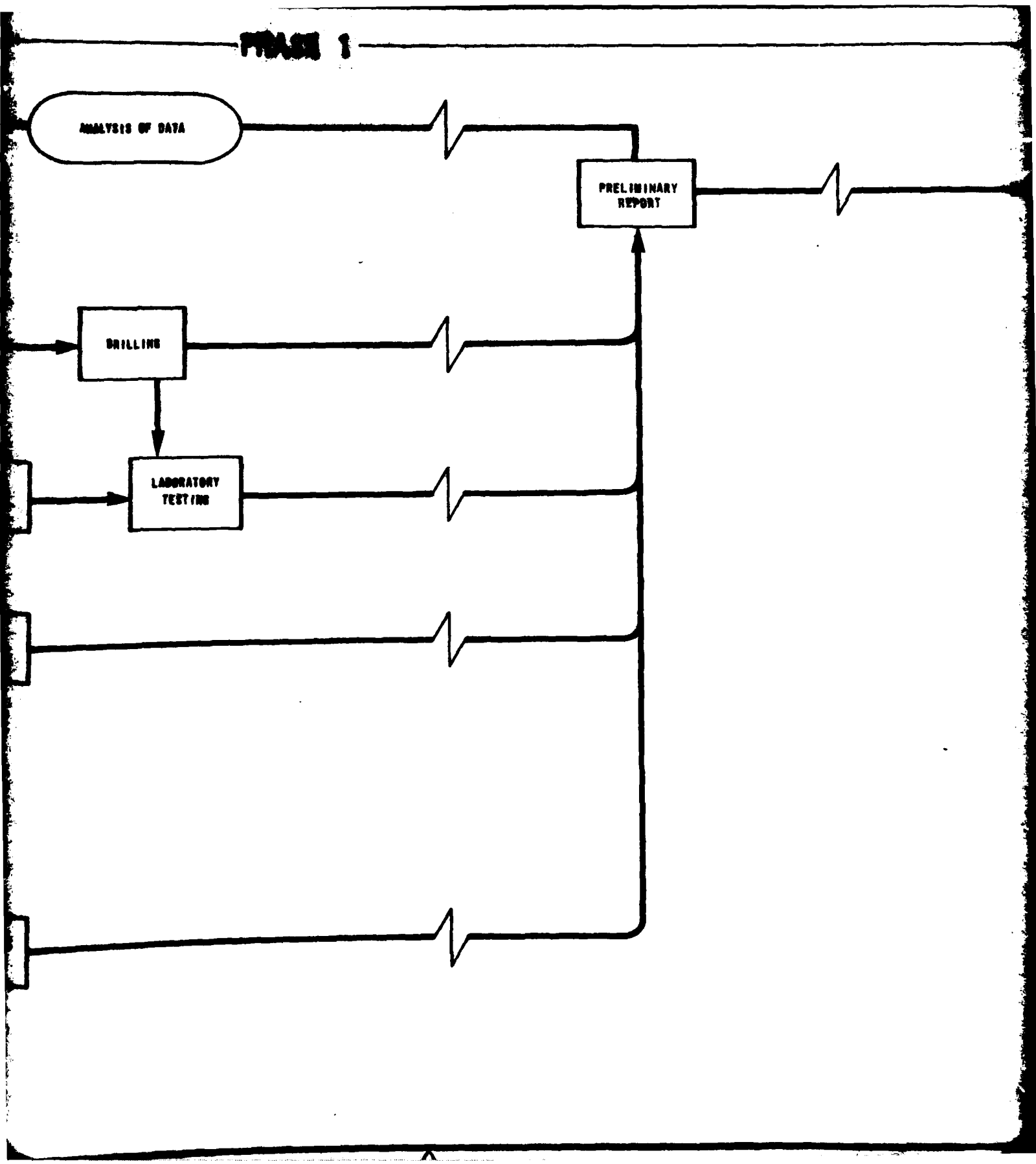
PHASE 1

ANALYSIS OF DATA

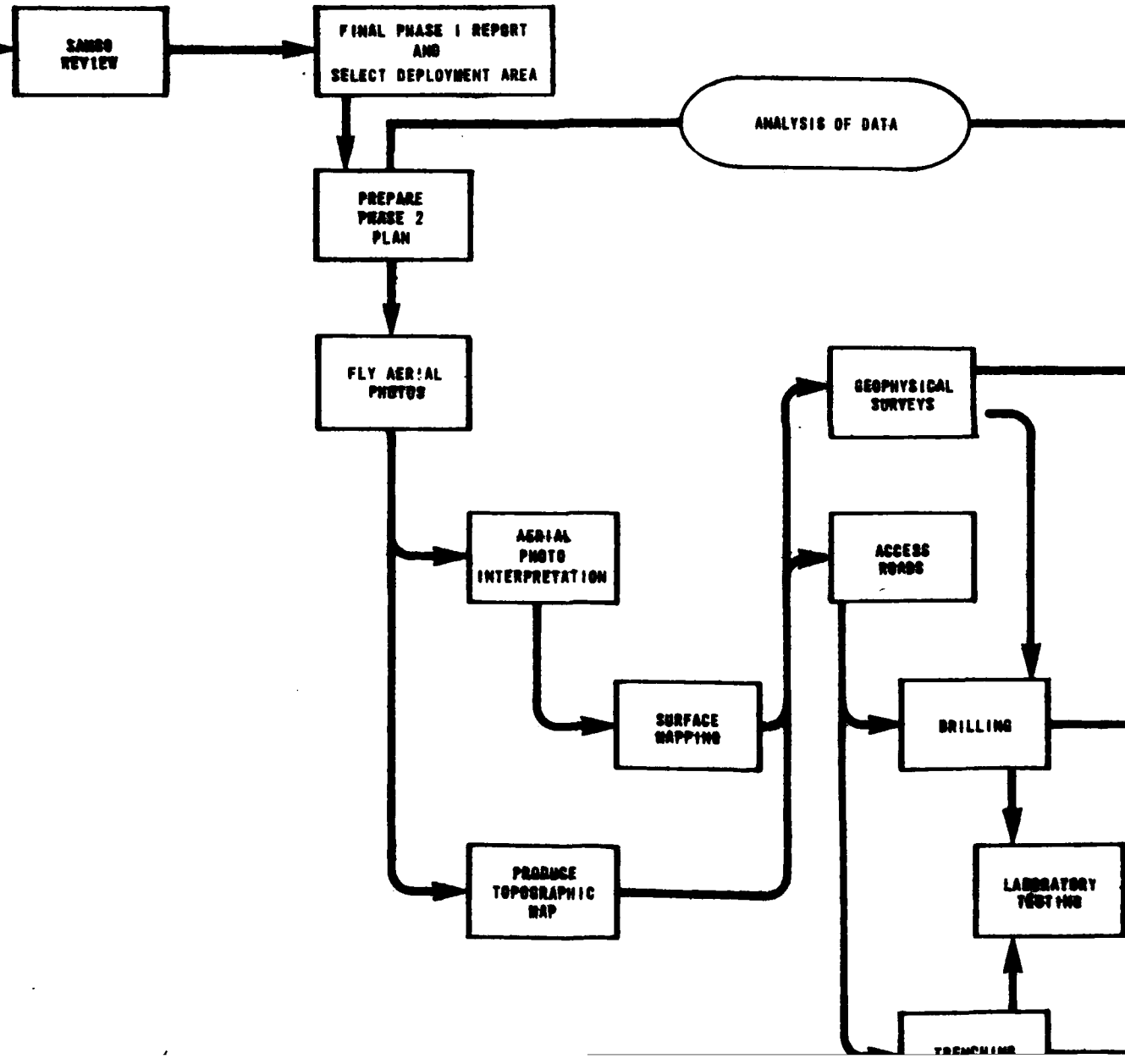
PRELIMINARY
REPORT

DRILLING

LABORATORY
TESTING



PHASE 2



PRELIMINARY
REPORT

SANSO
REVIEW

FINAL PHASE 2 REPORT
AND
SITE LAYOUT

ANALYSIS OF DATA

PREPARE
PHASE 3
PLAN

IN SITU
TESTING

GEOPHYSICAL
SURVEYS

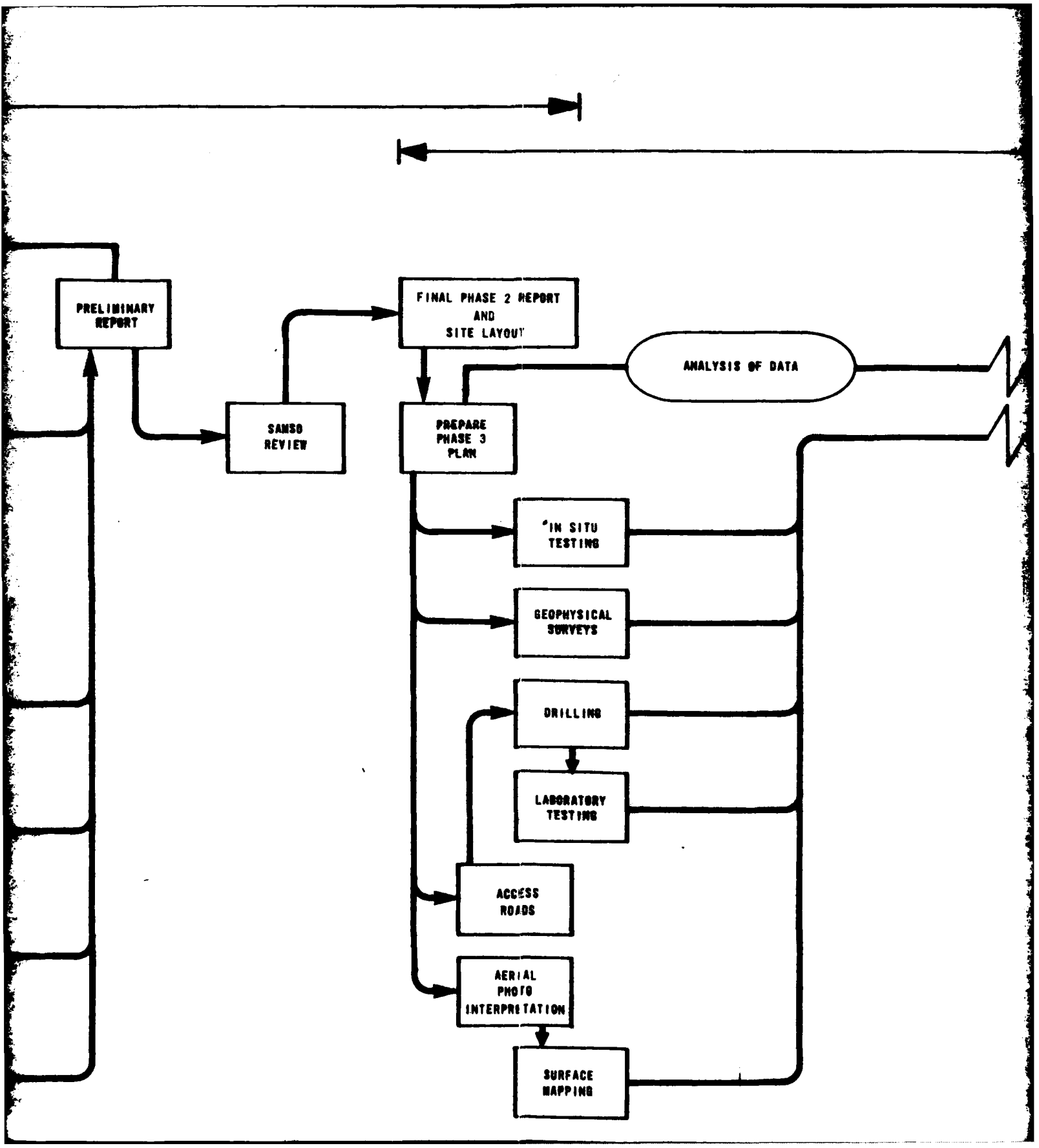
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LABORATORY
TESTING

ACCESS
ROADS

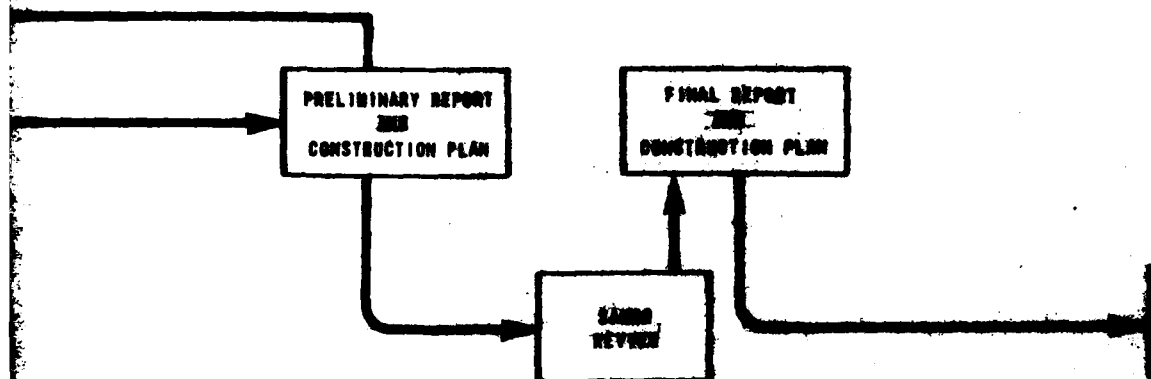
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INTERPRETATION

SURFACE
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


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PHASE 3



NOTES:

- (1) THIS DIAGRAM IS FOR SYSTEM DEPLOYMENT IN THE BLM LANDS AND IS EQUIVALENT TO TASK 14 AND TASK 15 OF THE PROGRAM PLAN
- (2) INDIVIDUAL TASK ACTIVITIES BEGIN AT THE LEFT OF ENCLOSED BOX
- (3)  THIS SYMBOL INDICATES A TIME BREAK FOR PURPOSES OF FIGURE SCALE CONTROL

**FLOW DIAGRAM - PHASED GEOTECHNICAL
BLM FIELD INVESTIGATION**

**MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMS**

**FIGURE
9**

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Each field technique shown in Figure 7 is presented in Tables 7, 8 and 9. Subordinate items within each technique are shown in Table 2.

3.0 STATUS OF EXISTING DATA

3.1 GENERAL

The quality of geotechnical data collected varies greatly in the three siting areas. In general, collected data depicted on the Data Summary Sheets of Volume II can be separated into three relative levels of reliability represented on Data Summary Sheets by the parenthetic symbol:

- 1) Data derived from detailed studies -- good reliability (●)
- 2) Estimated values -- moderate reliability (◐)
- 3) Insufficient data -- poor reliability (○)

Data derived from detailed studies include detailed site-specific and regional data generated from field studies that supplied valley-specific information such as location and thickness of volcanic flow rock, or grain size distribution and CBR of playa deposits. In general, recommended field work to supplement these data would be limited to investigations to confirm a prior analysis, or possibly no investigation with a certain technique would be recommended.

Data included in the estimated value category include mainly local or regional reconnaissance studies which may have limited specific supporting data points (e.g., drill holes, field observations, borrow pits). Such data have permitted reasonable, but not necessarily entirely reliable estimates of the geotechnical conditions present. Recommended field studies to supplement data in this category would consist

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of gathering detailed valley-specific field data to verify prior analyses and provide data to allow for more accurate estimates of the geotechnical conditions present where data were sparse.

The insufficient data category indicates either no data are available or that non-specific regional studies or unsupported personal opinions and assumptions were used based upon apparent similarity to areas of known conditions. Recommended field investigations for this category would involve detailed field investigation to develop sufficient data on all areas of the Valley for a reliable analysis.

3.2 QUALITY OF BLM DATA

There is a general sparsity of the kinds of data needed for siting of an MX system in the three BLM study areas. A summarized assessment of data quality for all Valleys is presented in Table 2. The individual symbol for each category represents an evaluation of the overall data quality based upon a qualitative analysis of individual Valley Data Summary Sheets as presented in Volumes IIA, IIB and IIC.

Specific depth to rock data are absent for most BLM Valleys. Limited data are available in some Valleys in both Nevada and Arizona, but are generally restricted to relatively small areas. General depth to rock data are available for some BLM Valleys in the form of gravity profiles provided by the Defense Mapping Agency. Those siting areas for which limited depth to rock data are available are shown in Table 2. In all Valleys a 100-foot depth to rock contour was estimated on the basis of available geologic, geomorphic and topographic data. These data are considered insufficient to provide the detail necessary for accurate depiction on the map.

Depth to water data are variable in the BLM Valleys ranging from insufficient in portions of the western Arizona and northern and eastern Nevada, to estimated values for most

TABLE 4
Summarized Assessment of Data Quality
for the Three Siting Areas

Siting Area	Principal Data Categories					
	Depth to Rock	Depth to Water	Other Parameters*			
			1	2	3	4
WSE	0	0	0	0	0	0
Gila Bend Group	0	0	0	0	0	0
Nellis Group	0	0	0	0	0	0

Data Quality:

- Data derived from detailed studies.
- Estimated values.
- Insufficient data available.

*Other Parameters:

1. Soils Engineering
2. Geology
3. Topography and Surface Hydrology
4. Groundwater conditions

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other Valleys. In the instances where data are available, depth to water is based upon regional groundwater studies by various state and federal agencies.

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4.0 PHASE 1

4.1 GENERAL

The Phase 1 investigation is specifically designed to:

- 1) Satisfy the important data deficiencies in the Data Summary Sheets (Volumes IIA, IIB, and IIC);
- 2) Provide a sound geotechnical basis for evaluation of the suitable BLM siting area with the level of confidence required for selection and definition, and location and size of the final deployment area; and
- 3) Provide preliminary design information to aid in validation of the selected concept.

It is not possible to quantify the degree of reliability attainable with this investigation. However, in relative terms, it is the goal of the investigation to be sufficiently reliable such that the selected concept will not likely be determined infeasible following additional investigation. Also, boundaries of suitable areas for siting and facilities locations (points and lines) should generally require only minor to moderate modification, with a few local minor changes, as a result of additional investigations.

Phase 1 data are to be used to update and revise the overlays and maps of Volume II. Specific information at a scale too small to be shown accurately on the overlays and maps will be precisely located on aerial photographs, kept as part of the permanent data bank for subsequent phases, and shown schema-

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tically on the appropriate overlays and maps.

An investigation based upon an idealized typical siting area having dimensions of 10 nm x 25 nm (250 nm^2) was established. This unit of investigation permits the flexibility required to account for the variability of siting valley conditions, and can easily be scaled up or down to actual dimensions for the specific investigation. Each BLM Valley will have a detailed field plan developed for it following the literature-based evaluation.

Table 3 presents the total number of 250 nm^2 unit areas in the BLM lands. These numbers are to be used as multipliers to determine program schedules.

TABLE 3
Number of 250 nm^2 Unit Areas in BLM Lands

Location	Total Available Siting Areas (nm)	Number of 250 nm^2 Unit Areas
Nevada	9,087	36.4
Arizona	2,387	9.6
New Mexico	<u>431</u>	<u>1.7</u>
Total BLM	11,905	47.7

Field techniques to be applied in the investigation of the approximately 48 unit areas include:

- 1) Production of aerial photographs;

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Field techniques to be applied in the investigation of the approximately 48 unit areas include:

- 1) Production of aerial photographs;
- 2) Ground and aerial magnetic and gravity surveys;
- 3) Interpretation of aerial photographs, infrared or other imagery (e.g., radar, thermal);
- 4) Surface mapping;
- 5) Geophysical surveys;
- 6) Subsurface exploration by drilling and trenching, and related sampling; and
- 7) In-situ field and laboratory testing.

It is not likely that all techniques will be utilized in every valley; the selection of investigative techniques will be based upon individual siting area characteristics and the advantages or limitations of each technique. The determination of which techniques are to be used will be based upon the reliability of existing data and the quality and quantity of data expected from selected techniques. Selection of techniques will be made during the field planning portion of Phase 1.

In addition to determining the field techniques in the planning portion of Phase 1, suitable areas for conducting Phase 1 field studies will be delineated. The primary factors for selecting these areas will be:

- 1) Application of established construction and nuclear

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weapons effects siting exclusion criteria;

2) Identification and application of C³ exclusion criteria;
and

3) Identification of areas where siting would not be
feasible based upon present or projected high use by
the government or co-use by the public (e.g., Central
Nevada Test Area, Desert Wildlife Refuge).

4.2 DATA TO BE OBTAINED

4.2.1 GENERAL

Phase 1 is designed to collect the specific types of data needed for an evaluation of the siting suitability of a valley. Three geotechnical categories for data collection have been identified along the top of Table 4. These are: depth to rock, depth to water, and other parameters (consisting of geologic, hydrologic and soils engineering properties of surface and near surface materials). All of the investigative techniques listed along the left side of Table 4 have data collection limitations.

In each valley area investigated, an equal data base will be established for the three geotechnical categories to an equivalent level of confidence. This will enable a valid and justifiable selection to be made of an area for deployment of the MX system. The level of investigative effort required in each valley will be based upon the quality and quantity of existing data obtained during the literature search in the BLM siting area.

Also presented in Table 4 are estimates of relative cost and relative reliability and versatility of the various techniques compared to the data required in the depth to rock and depth to water categories. Cost is divided into four parts--low, moderate, high and very high--and is considered as relative cost per data unit. Reliability/

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TABLE 4
Geotechnical Investigative Techniques

Investigative Technique	Depth to Rock		Depth to Water		Other Parameters
	Applica- bility	Cost	Applica- bility	Cost	
Geophysical					
Ground Gravity	A	Moderate	NA	--	NA
Ground Magnetism	A	Moderate	NA	--	NA
Aeromagnetics	A	Low	NA	--	A
Seismic Refraction	A	High	Very good	High	A
Seismic Reflection	A	Very high	Very good	Very high	A
Electrical Resistivity	A	Moderate to high	Good	Moderate to high	A
Remote Sensing (Aircraft and Satellite) and Aerial Photo Interpretation					
Photography	A	Low	Excellent (surface to very shallow only)	Low	A
Black and White					
Color					
Infra-red	A	Low	Good (surface or very shallow only)	Low	A
Imagery					
Thermal Infra-red					
SLAR					
Satellite (ERTS)	A	Low	Good (surface to shallow depths only)	Low	A
Surface Geologic Mapping					
Borings					
Soils Engineering (including in-situ testing)	A	Very high	Excellent (to 250')	Very high	A
Geology (including conventional and geophysical logging)	A	Very high	Excellent (250-2000')	Very high	A
Hydrogeology (including chemical and physical logging)	NA	--	--	Very high	A
Trenching					
In-Situ and Laboratory Testing	A	High	Excellent (to 25')	High	A
	NA	--	--	--	A

Notes: (1) Both shallow and deep.
(2) Includes sampling.
(3) Includes backhoe and bulldozer excavating techniques.

versatility factors are fair, good, very good and excellent.

In decreasing order of importance, these factors are based on nominal accuracy, amount of other useful data gathered concurrently, ease of performance, and affects on the environment.

Other parameters are determined either as "fall out" from the depth determinations or as specific items of investigation. The applicability of each technique is noted in Table 4.

4.2.2 DEPTH TO ROCK

Rock is defined as any geologic material having compressional wave velocities exceeding 8000 feet/second. The following depth to rock (and water) contours will be identified and depicted: 50, 100, 200, 250, 400, 800, 1600, 2000 feet and each 1000 feet thereafter. The level of confidence in depth measurements, in general, decreases with a greater depth to rock. Present knowledge of systems requirements indicates a much higher degree of confidence is required for the determination of rock depths within 250 feet of the surface than rock at depths greater than 250 feet.

For depth ranges of concern the following techniques (in order of importance) will be employed:

- 1) Zero to 250 feet -- seismic refraction, gravity/magnetics, drilling, and electrical resistivity;
- 2) 250 to 2000 feet -- seismic reflection, gravity/

- magnetics, seismic refraction, and drilling; and
- 3) Greater than 2000 feet -- gravity/magnetics and drilling.

4.2.3 DEPTH TO WATER

The water table is defined as the zone of saturation within basin-fill deposits, and does not include perched water conditions or water in rock aquifers. For Phase 1, the primary concern is in areas where the water table is within 250 feet of the ground surface. If water is encountered within this interval, techniques will be employed (Table 4) to refine the accuracy of the water contour. If water occurs at depths greater than 250 feet, only confirmatory data points will be established. Areas of perched water will be defined to the extent possible.

For depths less than 250 feet the most important techniques will be electrical resistivity, seismic refraction and drilling. For greater depths electrical resistivity, seismic reflection and drilling will predominate.

4.2.4 OTHER PARAMETERS

4.2.4.1 Soils Engineering

Specific construction related data on the near surface soils, and preliminary design information for vulnerability and hardness analyses on the soil column between

the ground surface and rock will be collected. The soils engineering data collection program will be addressed to both siting concepts and may be reduced in scope in some areas should a single concept be selected at the start of Phase 1.

Drilling, geophysics, laboratory and in-situ testing, and surface mapping techniques will be used most to gain soils engineering data. From the surface to about four feet, observations from surface geologic mapping will be most important. Drilling combined with laboratory and in-situ testing will provide much of the soils data down to 250 feet, with less detail to 2000 feet. Geophysical borehole logging, seismic refraction and, to a lesser extent, electrical resistivity will provide soils engineering data from zero to 250 feet and most of the data below 250 feet.

4.2.4.2 Surface Hydrology and Topography

The primary objectives regarding surface hydrology and topography in Phase 1 activities will be the delineation and documentation of stream channel morphology. Documentation will include definition and delineation of primary and secondary stream channels and their physical characteristics, and of flood or debris flow susceptible areas. Surface geologic mapping and interpretation of aerial photographs and imagery will be the primary field techniques employed.

Stream or flood flow gauging and refinement of percent slope conditions as shown on existing 1:62,500 scale maps is not part of Phase 1.

4.2.4.3 Geology

Surface geologic features previously defined in Volumes IIA, IIB IIC and the graphics volumes will be further refined by aerial photographic interpretation and field checking by surface mapping. Of particular concern are:

- 1) Geologic hazards such as mudflows, slump and landslide areas;
- 2) Location, limits and recency of movement of potentially active faults;
- 3) Limits of pediments and other occurrences of near surface rock;
- 4) Presence and limits of caliche and calcified or otherwise cemented basin-fill materials.

Subsurface geologic conditions down to 50 feet in depth will be noted as part of the soils engineering drilling and geophysics program. Deeper geologic information will be from geologic or hydrologic drilling, geophysical borehole logging and surface geophysics. Particular attention will be paid to the vertical and horizontal extent and physical nature of geologic units.

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4.2.4.4 Aquifer Characteristics and Water Well Development

If water is encountered in the valley, the deepest well will be pump-tested to provide physical parameters of the aquifer and typical well-yields. Since additional cost will be minimal, the pump-tested well will be developed for possible future domestic supply or for use as a source of water to supply construction and maintenance needs. Until the need for water actually occurs, the development and maintenance well will be capped with a sanitary seal to prevent contamination.

4.3 FIELD TECHNIQUES

4.3.1 GENERAL

The following investigative techniques are presented in the general sequence in which they will be conducted, with a discussion of the elements which will be defined through the use of each technique. Aerial photography and gravity surveys could be conducted by an appropriate government agency (e.g., Defense Mapping Agency). A computer-based data processing and retrieval system (including new software) should be developed for use in reduction and graphic presentation of data for all three phases.

4.3.2 AERIAL PHOTOGRAPHY

Color photography at a scale of 1:24,000 (one inch equals approximately 2000 feet) will be flown in the designated DoD and BLM siting areas, including both valley and mountain areas. Three copies of each 9 x 9 stereo pair and one positive transparency is to be provided. This scale aerial photograph obtained prior to beginning the field investigation will provide the following:

- 1) Photographic base for geologic, soils engineering and hydrologic mapping;
- 2) Convenient base for accurately locating and permanently documenting location of specific test sites (i.e., drill holes, gravity stations, seismic lines);
- 3) Plan access to field areas using existing roads and trails where possible; and
- 4) Current cultural conditions in the areas.

Black and white, and color infrared photographs may be required by other users including environmental contractors, land acquisition personnel, and program planners. Five copies and one positive transparency of each would be required. No new topographic maps are required for geotechnical work at this time. Selected production of topographic maps at a larger scale (e.g., 1" = 200') may be done to permit preliminary layout of sites and trial engineering calculations.

**4.3.3 GRAVITY, MAGNETOMETER AND AEROMAGNETIC
GEOPHYSICAL SURVEY**

Gravity, magnetometer and aeromagnetic surveys will be performed in selected valleys. The raw data will be reduced and presented in a mutually agreeable format and at a scale of 1:62,500. Ground gravity and magnetometer stations will be on a nearly-square one mile grid utilizing section corner monuments as control points if possible. Aeromagnetic survey flight lines should follow as nearly as possible the ground gravity and magnetic lines. In general, most lines should run normal to geologic structure (i.e., predominantly NNW and ENE).

The residual gravity, ground magnetometer and aeromagnetic data, as well as preliminary depth to rock maps will provide a reasonable estimate of basin configuration for planning the remainder of Phase 1, including geophysical survey line and drill hole locations.

4.3.4 ACCESS PERMITS

Obtaining access permits and permission to enter in BLM areas will be partially completed in the early stages of Phase 1. Permits and access permission should be obtained in a stepwise manner according to an agreed upon priority list in order to maintain program flow. This will also help to assure safe operating conditions prior to beginning field work in active bombing and gunnery ranges.

4.3.5 AERIAL PHOTOGRAPHIC ANALYSES AND SURFACE MAPPING

Interpretation of aerial photographs and field checking will be designed to obtain surface geologic, soils engineering and hydrologic data. Specific information will be recorded on the aerial photograph overlays. Field mapping and checking of interpretation will be conducted by two, two-man mapping teams supervised by an area coordinator. Aerial photo analysis plus field checking will require approximately 15 to 20 days per unit valley. In addition to mapping, surface bulk samples will be collected, and drilling, trenching and geophysical test areas will be located.

4.3.6 GEOPHYSICAL SURVEYS

4.3.6.1 Seismic Refraction

Ten to 20 seismic refraction profiles (spreads) are planned for each unit 250 nm² valley. Each spread will be 2400 to 3000 feet long, and require three shot holes drilled to depths of 20 feet. The resulting 30 to 60 drill holes will be logged at the time of drilling. In general, the surveys will be primarily planned to delineate depth to rock and general rock conditions within approximately 250 feet of the surface. Accuracies of rock depth determinations will vary with depth, but generally lie between five and ten percent. This program will also identify physical properties of the materials penetrated, and possible locations of zones of water saturation. The profiles will generally project

basinward from an area of exposed rock. Specific locations will be determined following completion of segments of the surface mapping program. A field team consisting of four persons, supervised by an area geophysics coordinator and siting area coordinator will be required to perform the work. Blasting powder totaling 50 pounds per spread will be required for this survey. Approximately ten field days will be required per 250 nm² unit valley area.

4.3.6.2 Seismic Reflection

Five to ten line miles of shallow to deep seismic reflection profiles in one to five miles long segments are planned for each unit valley. These surveys will be specifically planned to obtain data for rock conditions at depths greater than 250 feet and will supplement shallow depth to rock data obtained from refraction spreads near the mountain front. Depths to reflecting layers can be expected to be accurate within about five to ten percent. The specific locations of the surveys will be determined following analysis of reduced gravity maps and will be conducted at the same time as the seismic refraction profiles. A field team consisting of four persons, supervised by the area geophysics coordinator and siting area coordinator will be required to perform the work. Approximately ten field days will be required per 250 nm² unit area.

4.3.6.3 Electrical Resistivity

One hundred to 250 resistivity readings are planned in each

unit valley, primarily for the purpose of obtaining data on depth to water and depth to rock conditions. It can be expected that accuracies will vary with the array selected and the depth probed, but will generally be ten to 20 percent. The resistivity sounding program may consist of one, ten-foot receiver line and two 1000-foot source lines utilizing a portable 45 to 90 volt battery (AC) energy system. Soundings will be taken on the average of one per square mile. In general, the survey will be planned primarily to delineate rock and water conditions to depths of 1000 feet and will supplement the refraction and reflection programs. A field team will consist of three persons supervised by the area geophysics coordinator and siting area coordinator. Approximately ten to 20 days will be required to complete the survey for a 250 nm² unit valley.

4.3.7 DRILLING

A total of approximately 3000 feet of drill hole is planned for each 250 nm unit valley (Drilling Summary, Table 5). Of this total, at least one hole will be drilled to 1000 feet; the remaining 2000 drill-hole feet will be composed of several holes with minimum depths of 100 feet each. The deep hole(s) are drilled primarily to obtain information on depths to rock and water, and to determine the nature and thickness of basin-fill deposits. All holes will be sampled at regular intervals and

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TABLE 5
DRILLING SUMMARY

Task	Phase	Total Footage	Footage/ 250 mm	No. of Drill Holes x Depth (ft.) Per Hole	Primary Purpose	Sampling (1)
1	1	168,000	3000	1 hole x 1000/hole	Basin fill stratigraphy, depths to rock and water; physical properties	Continuous lithologic logs; *schedules a, b and c
				4 holes x 250/hole	Shallow stratigraphy, depths to rock and water	Continuous lithologic logs; *schedules a and b
				10 holes x 100/hole	Engineering properties, shallow stratigraphy, depths to rock and water	Continuous lithologic logs; *Schedules a and b
14	2	120,000 to 312,000	5000 to 13,000	2 or 3 holes x 1000/hole	Basin fill stratigraphy, depths to rock and water; physical properties	Continuous lithologic logs; and geophysical logs; *schedules a, b and c
				15 to 20 holes x 250/hole	Shallow stratigraphy, depths to rock and water	Continuous lithologic logs; *schedules a and b
				15 to 20 holes x 100/hole	Engineering properties, shallow stratigraphy, depths to rock and water	Continuous lithologic logs; *schedules a and b
15	3	740,000 to 900,000	1600 to 2000 (2)	14,400 to 18,000 holes x 50/hole	Engineering properties, shallow stratigraphy, depth to rock and water	Continuous lithologic logs; *schedules a and b

will have continuous lithologic logs recorded. Four drilling teams consisting of one technician and a two-man drill crew will be supervised by the area drilling coordinator and siting area coordinator. Approximately 15 to 20 days will be required to generate data per each unit valley area.

4.3.8 IN-SITU TESTING

In-situ testing will be conducted in selected drill holes for purposes of obtaining near surface properties of the materials. Scheduled tests may include:

- 1) Standard penetration tests,
- 2) Plate load tests,
- 3) Density and moisture tests, and
- 4) Cone penetration tests.

These tests will be conducted as part of the drilling program, with results noted by the drilling technician. Electric Cone Penetrometer testing will be conducted in fine grained soil areas.

Pump testing of the deep drill holes will be conducted over a 48-hour period to give both well yields and drawdown recovery records. The selected well will be logged by conventional and nuclear, downhole geophysical instruments. The development of the well and geophysical logging will require a three-man team supervised by the area drilling

coordinator and siting area coordinator. Approximately 3 to 5 days over and above drilling time will be required per unit valley area.

4.3.9 TRENCHING

Trenching will be conducted in conjunction with the soils and geologic mapping program. Approximately 2000 feet of trench, 25 feet deep and three feet wide is planned to be excavated for each unit valley. The primary use of these trenches will be to determine recency of movement on faults potentially capable of producing ground motion. Detailed trench logs will be produced in the zone of importance. Approximately 25 short test pits to depths of 25 feet will be excavated per unit valley, primarily for sampling of rock and basin-fill material in this interval. Bulk and undisturbed samples will be collected and the excavation materials tested and logged. Locations for the trenches will be determined following completion of the surface mapping program. Two teams consisting of one technician plus the operator will be supervised by the area drilling coordinator and siting area coordinator. Approximately ten to 15 field days will be required to generate data per unit valley area.

4.3.10 ACCESS ROADS

Access to drilling areas, geophysical testing areas and base camps will be limited, as much as possible, to

existing roads or areas accessible by four-wheel drive vehicles. A probable maximum of 25 nm of new road construction will be required per unit valley. These roads would be 20 feet wide and require a six inch minimum cut. Specific locations of the new roads will be determined by the area coordinator of the environmental engineer team following completion of the surface mapping program. Five to ten days will be required to construct access roads per unit valley area.

4.3.11 LABORATORY TESTING

Samples collected from drilling and trenching programs will be tested in the laboratory (Table 6). The following laboratory tests may be conducted for each unit valley:

- 1) Triaxial shear,
- 2) Direct shear,
- 3) Cyclic triaxial shear,
- 4) Resonant column,
- 5) Moisture content and density,
- 6) Grain size determination,
- 7) Compressibility,
- 8) CBR or R value, and
- 9) Maximum density.

TABLE 5
Soils Engineering Laboratory Tests

Soil Properties and Use	Laboratory Test	A.S.T.M. Designation
Classificatin for identifi- cation and design reuse.	Visual examination	D 2488
	Mechanical analysis	D 422
	Hydrometer analysis	D 1140
	Relative density	D 2049
	Atterberg limits	D 423, 424
	Specific gravity	D 854
	Sand equivalent	D 2419
	Maximum density/ optimum moisture	D 1557
	Permeability	D-2434
	Moisture-density	D 2415
Strength for foundation, pavement, and slope stability design.	Direct shear	none
	Triaxial shear	T 234*
	Unconfined compression	D 2166
	R-value	none
	CBR	D 1883
Compressibility for foundation design.	Consolidation	D 2435
Dynamic strength for soil response to earthquake and blast forces.	Cyclic triaxial shear	none
	Resonant column	none

*ASSTO designation.

4.4 DATA REDUCTION AND DEPICTION

All data received from the field teams will be used to update and modify the data obtained and depicted during the BLM literature search program. Data determined necessary for validation of Phase 1 conclusions and recommendations will be presented in the Phase 1 final evaluation report. All data not included in the Phase 1 final evaluation report will be placed in a permanent data bank. Finalization of graphics not put in the Phase 1 final evaluation report will continue during Phase 2. The general format for presenting data developed during the literature search phase will be used for presentation of Phase 1 data.

4.5 SELECTION OF DEPLOYMENT AREA

The Phase 1 final report will evaluate all data generated in the BLM lands studied and result in a selection of areas for the deployment of the MX System. At this time it is planned that:

- 1) A single MX concept will have been selected; and
- 2) Exclusion parameters for siting will have been identified and presented by all parties concerned, e.g., construction, nuclear weapons effects, C , and environmental groups.

A 2000 to 3000 nm² deployment area will be selected for Phase 2 detailed studies.

5.0 PHASE 2

5.1 GENERAL

The Phase 2 investigation will emphasize geophysical methods, soils engineering and detailed geologic mapping. Geophysical methods will define in greater detail depths to rock and water, aid determination of physical properties of materials, and locations and nature of construction materials. Soils engineering studies will consist of a detailed and intensive program of subsurface investigation, in-situ and laboratory testing. This work will be complemented by detailed geologic mapping.

For purposes of planning the Phase 2 studies the 250 nm² unit area is used. The total BLM area to be studied for Phase 2 is assumed to be between 2000 and 3000 nm . Field techniques to be applied in the investigation of a unit area, generally in order of performance, include: interpretation of aerial photographs, surface mapping, subsurface exploration by drilling and trenching, geophysical testing, and in-situ field and laboratory testing. The field techniques proposed will collect data to validate to a higher level of confidence the subsurface properties identified in the Phase 1 study. It is anticipated that the number of shelters or trenches to be constructed will be established prior to Phase 2.

Phase 2 will begin with a three month study to determine the specific plan. During this period limited field activities

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will be conducted. These activities will include obtaining larger scale aerial photographs, completion of new topographic base maps and possibly aerial photographic interpretation and surface mapping.

5.2 DATA TO BE OBTAINED

Phase 2 studies will be concentrated in areas that have been selected from Phase 1 as areas suitable for siting. Data obtained during Phase 2 studies will be used to further refine the data categories explained in Section 4.1 and further substantiate conclusions made during Phase 1. Minimum depth to rock and water criteria and other engineering and geologic construction and nuclear weapons effects criteria will be established.

Several studies may be initiated during Phase 2 in addition to the geotechnical programs. These include, but are not limited to:

- 1) Ecologic and archaeologic surveys to begin baseline studies in the selected areas, and
- 2) Meteorologic monitoring stations set up to begin baseline data collection.

These environmentally related programs will have involvement by various private and government agencies. The prime siting contractor will provide data and monitor results within the framework of the Phase 2 geotechnical program. Items of interest to both the geotechnical and environmental studies, such as aerial photographs, topographic maps, access permits and interdisciplinary reports will have their progress coordinated to assure mutual usefulness.

5.3 PHASE 2 FIELD TECHNIQUES

The field techniques used in the Phase 2 geotechnical program will generally be similar to the techniques initiated in Phase 1, but intensified in reduced areas. A greater emphasis will be placed on drilling and in-situ testing in the Phase 2 studies with a lesser emphasis on trenching and groundwater studies. The following techniques are tentatively planned for Phase 2 and are used for estimating schedules and costs.

5.3.1 AERIAL PHOTOGRAPHY AND BASE MAP PRODUCTION

Color aerial photography at a scale of 1:12,000 (one inch equals approximately 1000 feet) will be flown in the designated BLM siting valley deployment areas. Five copies of each 9 x 9 stereo pair and one positive transparency are required, with one copy of the negatives furnished for future use in preparing prints at an expanded scale. Ground control must be established prior to the flights in order to produce new topographic base maps.

New base maps of the total deployment area at a scale 1:1200 (1 inch - approximately 100 feet) with a contour interval of five feet will be prepared. These new base maps will permit refinement of the topographic conditions for intervals of zero to five percent, five to ten percent, and greater than ten percent topographic grades. Requirements for more detailed base maps (e.g., 1" - 50' and two-foot contour interval) necessary for construction could alter the base map production somewhat.

5.3.2 AERIAL PHOTOGRAPHIC INTERPRETATION AND SURFACE MAPPING

Interpretation of aerial photographs and field checking will define precisely the limits of geologic and soil units, locate and define potential areas for construction materials and determine specific locations for subsurface programs in the valley. Specific information will be recorded on the aerial photos for later transfer to the new base maps. Field mapping and interpretation of aerial photos will be conducted by four, two-man mapping teams supervised by the area coordinator. Aerial photo analysis plus field checking will require ten to 15 days per unit 250 nm² valley area.

5.3.3 DRILLING

Two drilling programs will be conducted in each unit valley (Drilling Summary, Table 5). The first will have two to three drill holes to depths of at least 1000 feet and perhaps deeper depending upon specific subsurface rock conditions in the Valley. These holes will be sampled at regular intervals (4.3.3 and 4.3.5) and will be continuously logged. Thirty to forty shallow holes will be drilled to depths of 100 to 250 feet. The purpose of these shallow test borings will be to:

- 1) Determine if water exists within 100 feet of the ground surface and, if so, its location and extent;
and
- 2) Provide information on soil conditions within the

upper 50 feet and the nature of geologic units to the completed depth of the hole.

These holes will have various suites of downhole geophysical logging to provide in-situ physical properties of these near surface materials and provide additional information on groundwater conditions.

Six to ten drilling teams consisting of one technician and a drill crew will be supervised by the drilling coordinator. Approximately 20 to 30 days will be required to generate specific subsurface data for each 250 nm² unit valley.

5.3.4 IN-SITU TESTING

In-situ testing will be conducted on the ground surface and in selected drill holes and trenches to obtain near surface properties of materials. Scheduled tests include:

- 1) Standard penetration,
- 2) Plate load,
- 3) Density and moisture, and
- 4) Cone penetrometer.

Electronic cone penetrometer testing will be conducted in fine-grained soil areas for purposes of recording in-place properties of materials to depths of 50 feet. This program will be conducted independently of the drilling program and will have footage not exceeding approximately 1000 feet.

5.3.5 SEISMIC REFRACTION

Ten to 20 miles of seismic refraction lines will be generally

located between boreholes. The purpose of these lines is to enable broad extension of the specific drill hole data as well as to provide additional specific information on the physical properties of the basin-fill materials. A field team will consist of four persons. Approximately 15 to 20 field days will be required per unit valley area.

5.3.6 TRENCHING

Shallow test pits excavated to depths of 25 feet will be logged to evaluate near surface conditions of the soil units. Bulk samples will be collected for laboratory analyses. It is estimated that a total of 500 feet of trench will be required for this purpose per 250 m^2 area.

5.3.7 LABORATORY TESTING

Samples collected from drilling and trenching programs will be tested in the laboratory. The following laboratory tests may be conducted for each unit valley:

- 1) Triaxial shear,
- 2) Direct shear,
- 3) Cyclic triaxial shear,
- 4) Resonant column,
- 5) Moisture content and density,
- 6) Grain size determination,
- 7) Compressibility,
- 8) CBR and R-value, and
- 9) Maximum density.

5.4 DATA REDUCTION AND DEPICTION

All data received from the field and laboratory investigations will be used to update and modify the data obtained and depicted during the Phase 1 siting area selection study. Data determined necessary for validation of Phase 2 conclusions and recommendations will be presented in the Phase 2 final evaluation report. All data not included in the Phase 2 final evaluation report will be finalized and placed in the permanent data bank.

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5.5 SITE SPECIFIC LOCATIONS OF MX CONCEPTS

Upon completion of Phase 2 field and laboratory activities and reduction of the collected data, specific locations of individual structures will be identified. By this time, all exclusions for siting must be identified. The specific locations of the shelters or trenches will be used for planning of Phase 3 activities.

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6.0 PHASE 3

6.1 GENERAL

The Phase 3 investigation will be performed to provide specific geotechnical information for construction of the selected concept at the specific locations of the MX system points or lines. The data obtained from Phases 1 and 2 will be used where it applies to specific sites, while the Phase 3 investigation will fill in data between the widely spaced data points of the first two phases.

A major portion of the field investigation will consist of shallow drill holes, one at each shelter location or along the trench alignment (Drilling Summary, Table IV). Shallow geophysical work will be performed in areas between borings, for the trench concept, or adjacent to the boring for the shelter concept. These techniques will refine the excavability characteristics of the materials, aid in determination of other physical properties and provide samples for testing in the laboratory. Aerial photographic interpretation will be conducted for engineering purposes at proposed sites or along alignments, and as necessary to define the areal extent of needed construction (borrow) materials.

The beginning of Phase 3 will be preparation of a detailed study plan incorporating the data gathered from Phases 1 and 2. Concurrently access ways for equipment will be constructed, site-specific topographic base maps prepared, and limited aerial photographic analysis performed.

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6.2 DATA TO BE OBTAINED

Data to be obtained will relate to excavatability of the soils at the location of the structure, stability of slopes in the excavations, foundation support of the shelters or trench conduit and support structures, back-fill of the structures, disposal of excess materials, design of road systems, and any other information pertinent to construction of the system.

Excavatability of materials is important to the costing of the construction of the structures. The presence of caliche and large boulders can significantly change the rate of excavation and, therefore, the cost. To prevent unforeseen difficulties with excavations it is planned to gain as much information as possible to identify the excavation properties of each site.

In order to avoid an excess amount of excavation and at the same time provide for safe, maintenance-free excavations, the stability of slopes will be analyzed. Cost of excavation can be directly related to amount of material moved. Therefore, a careful analysis will be made of the maximum slope angle possible for a safe excavation.

Support of the proposed structures will be analyzed both from a shear strength and settlement consideration. The

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arid soils are known to be highly compressible in some areas and the potential for significant differential settlement along a trench or within a shelter exists. These problems will be resolved and remedial measures recommended for avoidance of intolerable displacements.

Backfill of excavations will involve the compaction of soils above and around the structures. The soils will be evaluated to determine the most economical methods of backfilling to provide for the least amount of waste of material and eliminate depressions around or above structures from consolidation of backfill.

In addition to backfill the disposal of waste materials must be analyzed. Sites will be selected for disposal areas and methods of compacting the material in the disposal areas determined. All methods of disposal must be environmentally satisfactory. Specifications will be prepared for the compaction of both backfill and disposal materials.

Road systems either for transporter launchers or for maintenance vehicles will be investigated. Subgrade preparation, location and preparation of base course, and thickness of pavement materials determined if required. For this purpose, a number of road surface alternatives will be investigated.

6.3 FIELD TECHNIQUES

The methods used to provide the necessary construction information will be drilling, sampling and laboratory testing, geophysical testing, trenching, and in-situ field testing. All investigative methods will be applied to the upper 50 feet and at the specific shelter sites or along trench locations.

A drill hole will be placed at each shelter site or at one-half mile spacings along each trench alignment, selected in Phase 2. The boring will extend to between 40 and 50 feet deep and intermittent samples (usually 5 feet apart) will be obtained for laboratory testing. A complete log of each boring will be recorded during drilling describing the type of soil, consistency, moisture, and gravel and rock content.

Laboratory testing will consist of density and moisture content determinations, shear tests, consolidation tests, identification tests, CBR tests for pavement and maximum density, optimum moisture content determinations. Representative samples of the soils will be retained in the laboratory for further reference.

Geophysical testing will be performed at each shelter site or along the trench alignment to determine the compressional wave velocity of the upper 50 feet of soils. This information will be used to evaluate continuity of the soils around or between borings and to locate caliche zones which may create excavation problems.

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Trenching will be performed at selected locations to observe near surface materials for select borrow and for in-situ testing. Trench locations will be made based upon specific site conditions.

In-situ testing will consist of plate load tests, California Bearing Ratio tests and cone penetrometer tests. This testing will be selectively used based upon expected soil conditions, the applicability of the test method, and the data requirements.

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6.4 DATA ANALYSIS AND PRESENTATION

Data gathered from the field and laboratory investigations will be analyzed and applied to the selected design. A separate report will be prepared for each trench alignment or each shelter location containing the results of the field and laboratory investigations together with recommendations for final design and construction of that system component. The data will be presented for each location on maps, on tables, on boring log forms, and in text for review by designers and constructors.

The maps will present the final trench or shelter location. It is anticipated that some minor changes in location will be required during analysis of the Phase 3 data, but these changes should be minor.

7.0 RECOMMENDED PHASE 1 GEOTECHNICAL INVESTIGATION

Tables 6 (White Sands Extension), 7 (Gila Bend Group), and 8 (Nellis Group) show recommended investigative techniques which may provide the necessary data to properly evaluate the geotechnical conditions affecting siting suitability during the Phase 1 field program (Table 4). The relative level of a geotechnical field effort for each siting valley is assigned for each technique and ranges from No Investigation Currently recommended to Extensive Investigation Required. Quality of data (Section 3.0) in a Valley is directly related to the level of effort required in the field investigation. This relationship is as follows:

Data derived from detailed studies

No investigation currently recommended or limited investigation required to confirm prior analyses.

Estimated values

Investigation required to obtain sufficient new data to verify prior analyses.

Insufficient data available

Extensive investigation required to develop sufficient data for analyses.

An investigation technique may not be recommended (NR) in a particular Valley if: 1) sufficient data are available in the Valley such that the technique may not be warranted; 2) the Valley is of limited areal extent such that the technique may be cost prohibitive; or 3) conditions exist in a significant portion of a Valley which could restrict data retrieval by the method, therefore making an alternate method more appropriate.

A limited field investigation (; Tables 6, 7, and 8) includes studies primarily to assess conditions as determined during

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the literature search, to provide specific confirmatory programs in a Valley of small areal extent, and to provide some new data from existing sources (e.g. wells, borrow pits).

The application of an investigative technique to obtain sufficient new data to confirm prior analyses () includes expansion of prior programs to collect and/or reinterpret data for specific application to MX siting.

An extensive data collection program () includes generation of new data where none presently exists, or where existing data are inadequate for reasonable analyses.

As shown in Tables 6, 7 and 8, reconnaissance techniques can provide data for more than one siting consideration. The first letter (preceding the comma) indicates the primary consideration for which the program will be designed. Data to be derived for other parameters follow, generally in order of importance. For example, RW,O indicates that an extensive investigation is proposed for a Valley primarily for the purposes of obtaining depth to rock (R) and depth to water (W) data. In addition, data on other parameters (O) will also be obtained.

Tables 6, 7, and 8 summarize the level of effort required in each siting area. Supportive information for these levels were derived from the Data Summary Sheets of Volumes IIA, IIB, and IIC. In general, the intensity of the recommended field efforts will be least in the White Sands Extension and greatest in the Gila Bend Group. The Nellis Group, with the exception of the Central Nevada Test Area, will require an effort slightly

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less than the Gila Bend Group. Since the magnitude of Phase 2 field studies will be highly dependent on Phase 1, the results of which should be near-equal data base in all Valleys, no attempt is made here to present a Phase 2 level of effort.

RECOMMENDED GEOTECHNICAL

SITING VALLEYS

Jornada del Muerto Valley North	△	△	△	△	△	△
	△	△	△	△	△	△
	△	△	△	△	△	△
	△	△	△	△	△	△
	△	△	△	△	△	△
	△	△	△	△	△	△
	△	△	△	△	△	△
	△	△	△	△	△	△
	△	△	△	△	△	△
	△	△	△	△	△	△
	△	△	△	△	△	△
	△	△	△	△	△	△
	△	△	△	△	△	△
	△	△	△	△	△	△
	△	△	△	△	△	△
	GRAVITY	AERO-MAGNETIC	SEISMIC REFRACTION	SEISMIC REFLECTION	ELECTRICAL RESISTIVITY	PH
GEOPHYSICAL TECHNIQUES						

EXPLANATIO

LEVEL OF INVESTIGATION

- NR No investigation currently recommended
- △ Limited investigation required to confirm prior analyses
- △ Investigation required to obtain sufficient new data to verify prior analyses
- △ Extensive investigation required to develop sufficient data for analyses

SITING PARAMETERS

- R - Depth to Rock
- W - Depth to Water
- O - Other parameters
- soils engineering
 - geology
 - topography and surface hydrology
 - groundwater (quantity and quality)

RECOMMENDED GEOTECHNICAL

SITTING VALLEYS	Cactus Plain	△	△	△	△	△
	Butler Valley	△	△	△	△	△
	McMullen Valley	△	△	△	△	△
	La Posa Plain	△	△	△	△	△
	Ranegras Plain	△	△	△	△	△
	Harquahala Plain	△	△	△	△	△
	Palomas-Hyder Valley	△	△	△	△	△
		△	△	△	△	△
		△	△	△	△	△
		△	△	△	△	△
		△	△	△	△	△
		△	△	△	△	△
		△	△	△	△	△
	△	△	△	△	△	
	GRAVITY	AERO- MAGNETIC	SEISMIC REFRACTION	SEISMIC REFLECTION	ELECTRICAL RESISTIVITY	
	GEOPHYSICAL TECHNIQUES					

EXPLANATION

LEVEL OF INVESTIGATION

NR	No investigation currently recommended
▲	Limited investigation required to confirm prior analyses
▲▲	Investigation required to obtain sufficient new data to verify prior analyses
▲▲▲	Extensive investigation required to develop sufficient data for analyses

SITING PARAMETERS

- R -- Depth to Rock
- W -- Depth to Water
- O -- Other parameters
 - soils engineering
 - geology
 - topography and surface hydrology
 - groundwater (quantity and quality)

SITTING VALLEYS

EXPLANATI

SITING PARAMETERS

No investigation currently recommended

Limited investigation required to confirm prior analyses

Investigation required to obtain
sufficient new data to verify
prior analyses

Extensive investigation required to develop sufficient data for analyses

W - Depth to Water

- soils engineering

- geology

- topography and surface hydrology

- groundwater (quantity and quality)

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8.0 CRITICAL MS SITING ELEMENTS

8.1 GENERAL

The Phase 1 investigation follows a logical sequence of procedures designed to produce information covering the BLM areas lacking sufficient data to evaluate MX siting suitability. The study will, by plan, be broad in scope. Although all areas of design will be covered by the three phased investigation, it may be desirable to investigate certain critical concept features which affect the progress of the system design. For this reason, critical MX siting elements have been identified which may be investigated in separate studies carried out concurrently with the Phase 1 study.

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8.2 SHELTER CONCEPT

The shelter concept appears to require the least consideration to unusual construction techniques and, therefore, the fewest special design questions from a geotechnical point of view. However, two areas of concern may be investigated to more clearly define the construction techniques at an early stage:

1. Excavatability. Caliche may be a serious problem requiring blasting. A special study combining drilling, interpretation of multispectral aerial photographs and geophysics could be performed on the older and intermediate alluvial fan units.
2. Surface Runoff Control. The extensive road network required by this concept will disrupt the natural surface flow of storm waters. A detailed study of the surface hydrologic characteristics of several Valleys could provide valuable design data regarding quantities of storm water to be handled by the road drainages and probable performance of various drainage structures under high flash flood conditions.

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8.3 TRENCH CONCEPT

The trench concept as currently characterized calls for the use of a special excavating machine as well as special drainage crossings along the ten nm trench lengths. The following list presents possible special studies associated with the trench:

1. Excavatability. (same as shelter concept)
2. Slope Stability. A major consideration which may affect the design of a special excavating-slipforming-backfilling machine is slope stability of the trench walls while the slip-form operation progresses. This consideration along with the excavatability of caliche influences the design of the machine to such an extent that the results of a detailed study of a small area may influence the entire construction approach of the trench concept. A special study of the known surficial geologic units to determine what angle of repose will be necessary to assure reasonably stable trench sides during construction may be warranted.
3. Drainage Crossings. An area of special study related to the trench concept is both major and minor drainage crossings. This study would evaluate more accurately than has presently been done (a) the typical number and sizes of drainages to be crossed, (b) the important relationship between sizes of drainages and the rate at which water is anticipated to flow during flooding, (c) the quantity of included debris, and (d) the resulting force applied to a trench structure passing through a drainage by the flows and debris.